Start on 490

LAKE ENHANCEMENT PROGRAM
FEASIBILITY STUDY
FOR
HUNTINGBURG LAKE

Final Report — after revision

Prepared for:

THE CITY OF HUNTINGBURG
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EXECUTIVE SUMMARY

Huntingburg Lake, located in Dubois County, is a man-made water supply reservoir with an average surface area of 147 acres, a mean depth of 12 feet, a maximum depth of 24 feet and a 1043.5 acre watershed. The lake is situated on Ell Creek, a tributary of the Patoka River, 1.3 miles west of the City of Huntingburg. Much of the drainage of the predominantly agricultural watershed enters the lake through five, unnamed tributaries from the south. There is development along the southern and western lakeshore in private, single-family residences, and along the eastern shore as a private country club and golf course. Problems concerning aquatic vegetation, rough fish populations, sedimentation and turbidity have been reported since the early 1940s.

The objectives of this feasibility study were to assess the current characteristics of the lake and the surrounding watershed, identify the eutrophication problems, their sources and relative contributions, develop restoration alternatives, and recommend the most appropriate and potentially successful alternative.

Currently, Huntingburg Lake is undergoing the consequences of excessive nutrient and sediment loading as a consequence of cultural eutrophication. The evidence is the nutrient concentrations in storm runoff, decreasing transparency readings, the bacterial counts of the lake water, the extent of emergent aquatic vegetation along the shoreline, and the nutrient concentrations present in the lake sediments.

The primary sources of nutrient and sediment loading are the agricultural pastures and croplands. This influx of nutrients results in the consequences of extensive algae and macrophyte populations, contributes to the turbidity of the lake water, and provides for the enrichment of the lake sediments. The watershed soils are almost exclusively classified as highly erodible. The conventional tillage practices and the grazing of livestock on these types of soils within particular areas of the Huntingburg watershed is rapidly decreasing the water quality of the lake. These areas should either be converted to permanent ungrazed meadowlands or cropped using a proposed 5 year reduced tillage/crop rotation plan that will reduce erosion. Additional benefit from the implementation of streamside management zones providing for buffer zones along the lake and its tributaries is also recommended. Watershed erosion control techniques would be designed and implemented by the SCS and the IDNR Erosion Control Technician for Dubois County as a part of the T by 2000 Cropland Erosion Control Program on a cost-share basis with the landowner. Funding may also be available through the Agricultural Stabilization and Conservation Service (ASCS) through the CRP program, the Feed Grain program, or the Agricultural Conservation program.

The restoration of Huntingburg Lake must secondly concentrate on a significant reduction in septage loading. Reduction of nutrients and bacterial counts will primarily be accomplished through the construction of small alternative wastewater systems. These systems would make use of functioning residential septic tanks and small diameter lines to collect the septic effluent and pump and/or gravity drain it to the existing city sewer lines. The cost of these systems can be one-fourth to one-half the cost of a conventional sewer system, from $2000 to $4000 per residence based on such conditions as soil characteristics, topography, and distance between residences and the city sewer lines. There are approximately 35 residences on the lake watershed, with 20 in close proximity to the lake or its tributaries.

To provide for further sediment control and removal of accumulated nutrient-rich sediments, we recommend that the marsh area of the lake, the west leg south of County Road 630 South, be dredged for the removal of 13,020 cubic yards of nutrient-rich sediment. The typical dredging cost for this sediment removal can range between $2 to $5 per cubic yard, depending on method of removal. A permit from the U.S. Army Corps of Engineers may be required for the dredged material, and a Construction in a Floodway Permit will be required by the Indiana Department of Environmental Management. It is further recommended that mitigation techniques be designed to treat and/or control the acid mine drainage originating from the abandoned clay mines.

The remaining recommendation is that a management plan be established for the lake and its watershed. The management plan should incorporate both short and long-term planning and be based on city regulations and/or ordinances. Officials of the City of Huntingburg and Citizens,as well as other concerned users of the lake, should be made aware of the management plan, its purpose and its necessity to the long-term quality of the lake as the City's primary water facility.

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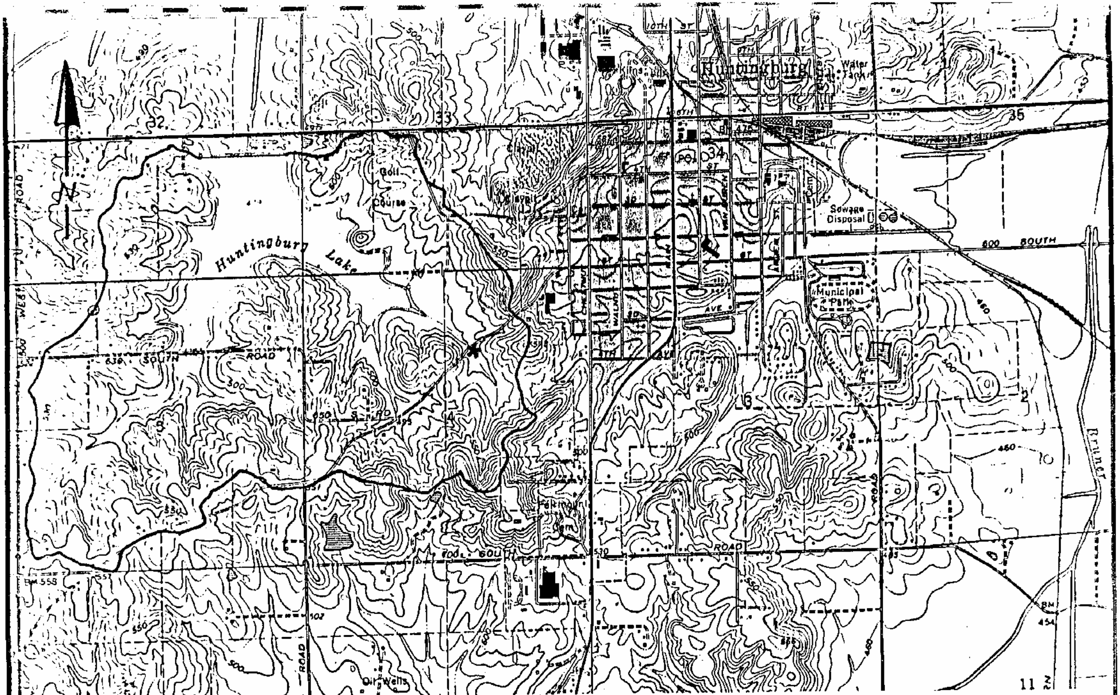
1.1 Huntingburg Lake and Watershed

Huntingburg Lake is located in Dubois County, 1.3 miles west of the City of Huntingburg. The lake lies within Sections 32 and 33, Township 2 South, Range 5 West and Sections 4 and 5, Township 3 South, Range 5 West on the U.S.G.S. Huntingburg 7.5-Minute Quadrangle Map dated 1969, photorevised in 1980.

Huntingburg Lake is the primary water facility for the City of Huntingburg (Figure 1). It has a surface area of 147 acres, a mean depth of 12 feet, a maximum depth of 24 feet, and a 1043.5 acre watershed. The shoreline of the lake is developed with private, single-family residences, and a privately-owned country club, as well as an Indiana Department of Transportation road-side park and a public boat ramp maintained by the City. The watershed is predominately agricultural with a majority of the drainage entering into the lake through five, unnamed tributaries from the agricultural sub-watersheds. The lake discharges into Ell Creek through by means of a concrete spillway located on the northeast side of the lake.

The lake has been characterized as a warm, shallow and fertile lake with a bottom of muck, sand and clay (Fish Survey Report, 1976). Past aerial photography and fish survey reports show that the watershed has consistently been predominately agricultural, up to approximately 65 percent (Fish Survey, 1984). Residential development has been progressive until recently. Within areas of the eastern edge of the watershed, clay pits and clay shaft mines were active until the late



LEGEND

WATERSHED BOUNDARY

* ACID MINE SEEP

TOTAL LAKE ACREAGE 147 AC

TOTAL WATERSHED ACREAGE 1043.5 AC

FIGURE 1.
HUNTINGBURG LAKE

SCALE
0 2000
FEET

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1950s. Related to these mines, an acid mine seep is located near the most eastern tributary feeding into the lake.

1.2 Water Quality Problems

Since the mid 1960s, Division of Fish and Wildlife fish management reports have noted problems of turbidity, excessive emergent aquatic vegetation along the lake shore limiting fishing access, and rough fish populations. The City has had some problems with turbidity and post-treatment water quality, specifically manganese, and has had concerns regarding lake shore residential development, agricultural practices on the watershed, and the apparent stressed condition of many of the lake's fish populations.

1.3 Feasibility Study Objectives

The objectives of this study were to assess the current characteristics of the lake and the surrounding watershed, along with the identification of historical and existing eutrophication problems, their sources and relative contributions, the development of restoration alternatives, and the recommendation of the alternative found to be the most practicable and potentially successful. This study included historical lake data and watershed land usage (Section 2.1), field surveys and sampling programs (Section 2.2), analysis of data (Section 3), restoration alternatives (Section 4), the preferred alternative, conclusions and recommendations (Section 5), along with references.

SECTION 2. DATA COLLECTION

2.1 Historical Data

An Indiana State Board of Health public water supply report, dated June of 1955, described Huntingburg Lake as a set of three impounding reservoirs composed of east, middle and west lakes (Figure 2). The east lake, constructed in 1893, had a surface area of 23.5 acres and a maximum depth of 10 feet. The middle lake constructed in 1913 had a surface area of 22.5 acres and a maximum depth of 15 feet. The west lake, constructed in 1933, had a surface area of 109 acres and a maximum depth of 22.5 feet. The approximated total lake surface area at that time was 155 acres. The water level was temporarily raised about one foot in 1955, with the dam and spillway permanently raised about two feet in 1966 (pers. comm. Loma Hartke). To provide for boat access, the two submerged dams were cut near their centers (pers. comm. Loma Hartke).

An earlier USDA Soil Conservation Service report dated May of 1941, records that a sedimentation survey was conducted by the USDA Soil Conservation Service on October 21, 1940, of the east lake also referred to as the upper lake. The sediment was found to be a loose, gray silt or clay with a mottled effect, sometimes with a brownish or yellowish cast. The greatest accumulation of sediment was immediately above the dam, with a maximum depth of 5.2 feet. Water flow over the spillway was reported to occur only five percent of the time. The report had the estimated loss of original capacity at 13.14 percent.

Another sedimentation study was initiated in March of 1988

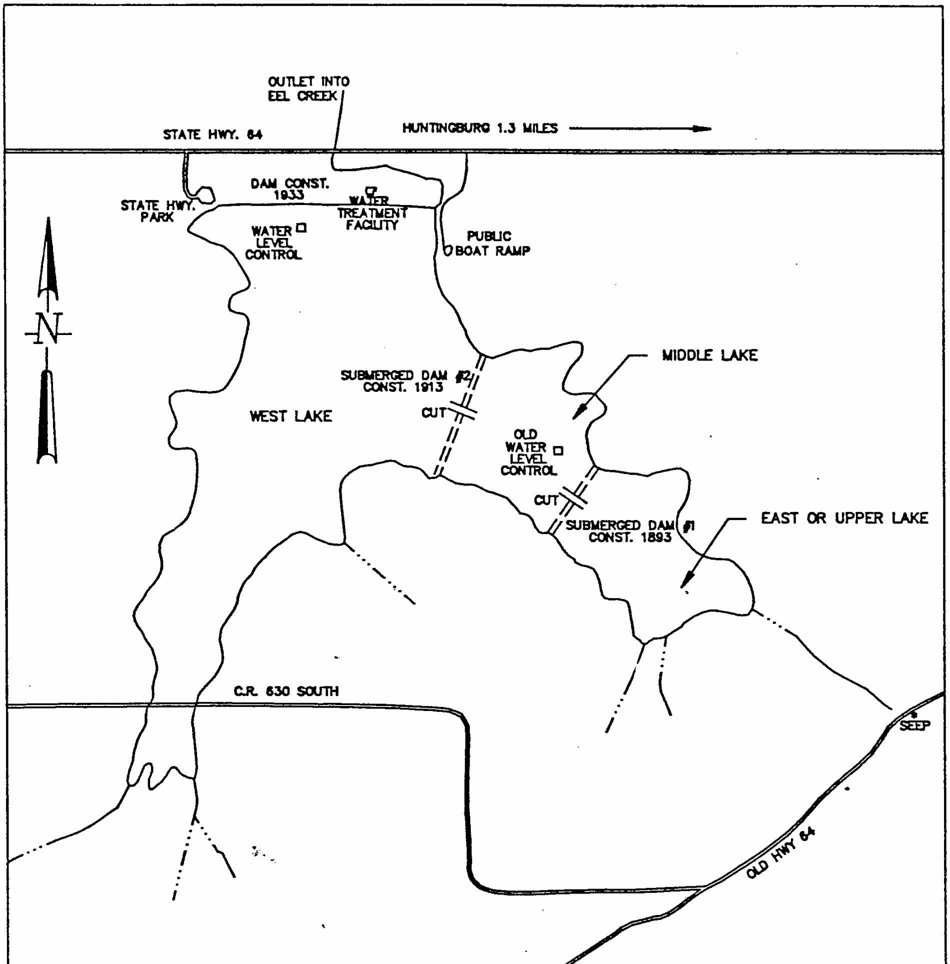

FIGURE 2.
HISTORICAL FEATURES OF HUNTINGBURG LAKE

SCALE
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to determine the volume of sediment to remove from the marsh area located on the west leg of the lake and south of County Road 630 South (Midwestern, 1988). The survey determined that 13,020 cubic yards would require removal. This part of the lake has functioned as the natural silt basin for subwatersheds 5 and 6 (See Subwatershed Definition Map in the Appendix), which are predominantly agricultural lands with row crop and pasture uses. The elevations at that time were 476, and 478 feet (msl). The area was recommended to have sediment removed to establish elevations of 474, 476 and 478 feet as shown in Figure 3.

Indiana Department of Natural Resources, Division of Fish and Wildlife, conducted lake surveys of Huntingburg Lake in 1964, 1968, 1969, 1973, 1976, 1981, and 1984. Lake data was recorded for the years 1973, 1976, and 1984. As shown in Table 1, Secchi disk readings have decreased from 5.0 feet in 1975 to only 2.5 feet in 1990. In the 1964 report, the turbidity of the water is mentioned with the cause thought to be the rooting action of the rather large carp population. Submerged aquatic vegetation, mainly <u>Najas gracillima</u> - a common species of naiad, covered all shallow areas to a depth of five feet, and was thought to be limited by the turbidity of the water. The upper ends of the lake also showed evidence of silting. In this 1964 report, the remark was made that the fishing had been good in the past, but had been getting worse during recent years. In 1965, the large population of gizzard shad and carp required a complete eradication of all fish with a 1 ppm application of rotenone approved by the State Board of Health

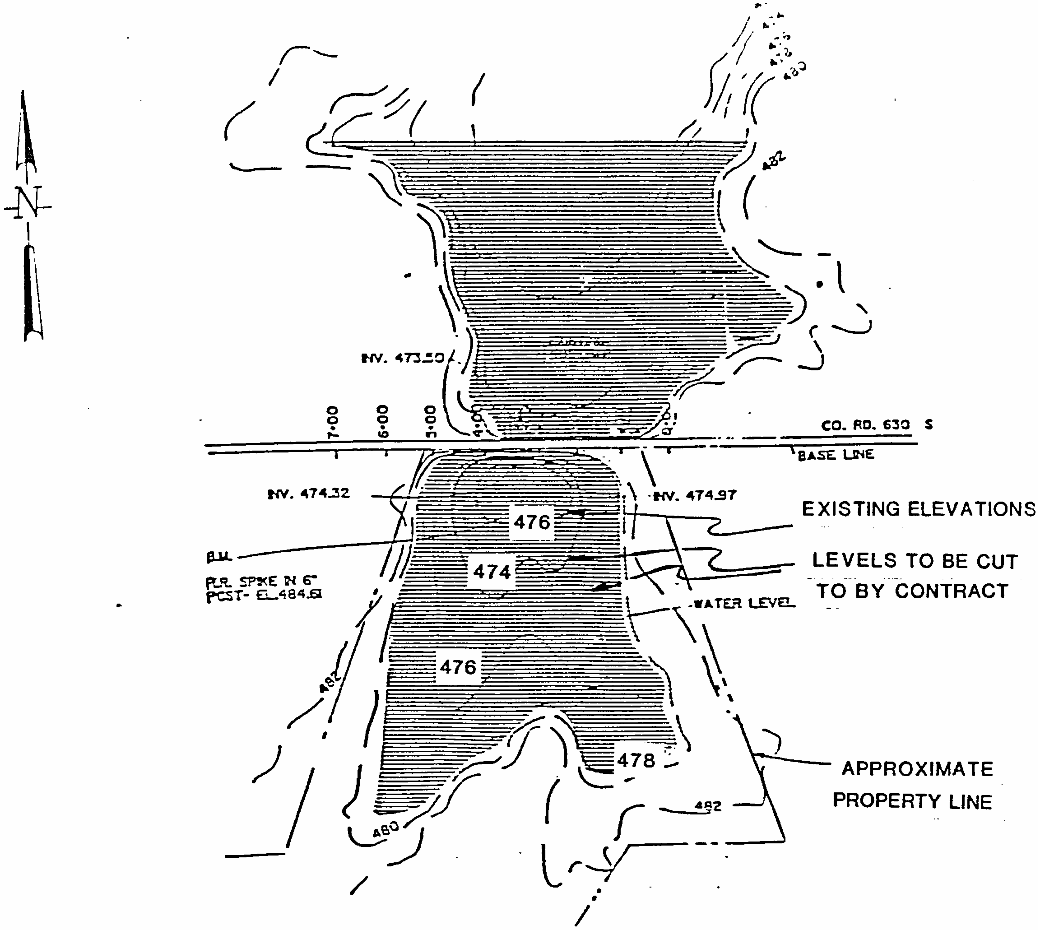

FIGURE 3.

HUNTINGBURG LAKE SILT BASIN AREA WITH ELEVATIONS

SUPPLIED BY THE
CITY OF HUNTINGBURG
SURVEYED 1988 - 1989

and the subsequent restocking of desirable species. A survey in 1966 showed the stocking of largemouth bass, bluegill, and redear sunfish successful, however it also showed the presence of some carp and shad (Fish Mgt. Report, 1969). The survey in 1968 and 1969 showed the carp and shad populations stable due to the bass predation, and the overall fish population structure improved. Recent surveys, in 1981 and 1984, show that there is an abundant forage base of carp, gizzard shad, and assorted sunfish, most of which is not utilized by predators (Fish Mgt. Report, 1984). There is a healthy bass population though, with Huntingburg Lake known as a "lunker" bass lake (pers. comm. Paul Glander). Fish stockings since 1979 have attempted to establish another predator species by stocking channel catfish, tiger muskie, and white bass. The stocking of tiger muskie and white bass have been unsuccessful and it is assumed to be due to the turbidity of the water impairing their ability to hunt by sight (Fish Mgt. Report, 1984). Since this 1984 report, channel catfish have been stocked in 1986 and 1989, along with saugeye (walleye X sauger hybrid) in 1988 and 1989 (pers. comm. Paul Glander). Saugeye have been shown to be more tolerant of the warm, turbid conditions typical in shallow, fertile impoundments.

TABLE 1.

HUNTINGBURG LAKE HISTORICAL WATER QUALITY PARAMETERS

SOURCE	DATE	COLOR	SECCHI DISK	D.O.@5 FIT	pH
Donan Eng.	Aug. 89	tea-brown	2.64 ft	88%	7.3
Div. F & W	Sept. 84	brown-green	2.75 ft	117%	8.0
Div. F & W	Aug. 76	---	4.9 ft	129%	7.5
ISBH	July-Sept. 75	---	5.0 ft	---	---
Div. F & W	May. 73	green-brown	3.4 ft	94%	7.2
Div. F & W	Nov. 64	---	(turbid, no data)	---	---

During September of 1987, the Indiana State Board of Health, Division of Sanitary Engineering conducted an on-site soil evaluation pertinent to residential sewage disposal. Six borings of the soil were conducted at various locations around the reservoir (Figure 4). Soil conditions represented by borings 2, 4, 5 and 6 were determined to be unsuitable for any on-site sewage disposal system due to low permeability, fragipans, slopes exceeding 12 percent, and shallow depth to rock. In contrast, soil conditions at borings 1 and 3 were

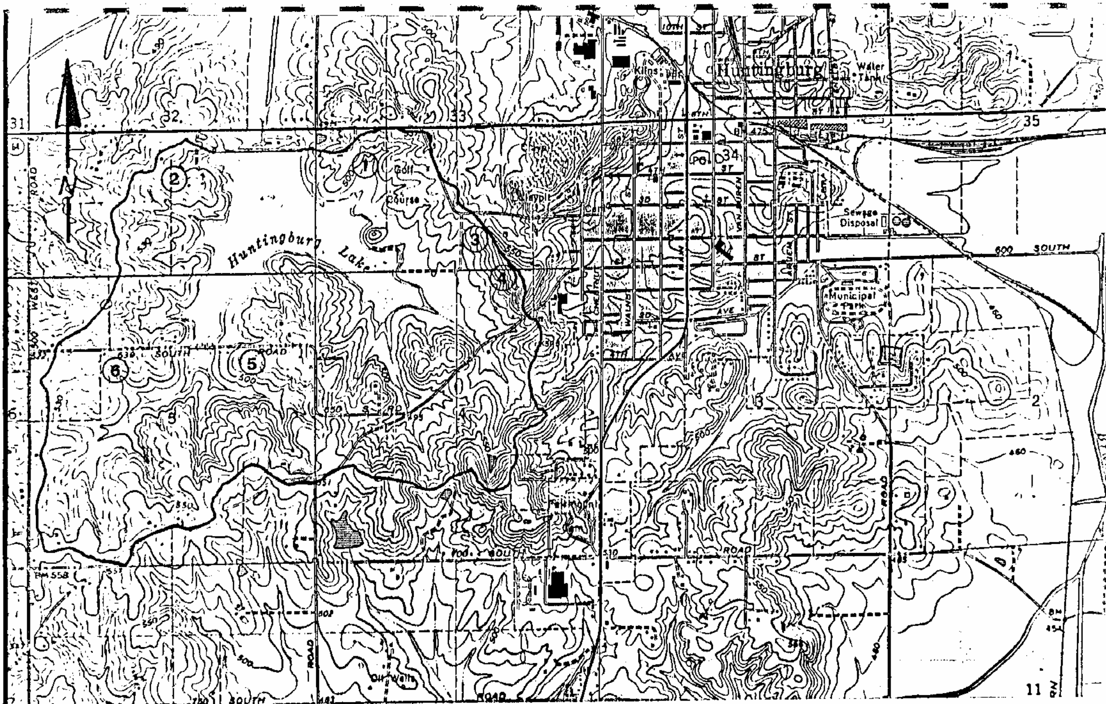

FIGURE 4.
HUNTINGBURG LAKE

LEGEND

WATERSHED BOUNDARY

ISBH SOIL SURVEY AREAS

SCALE

0 2000

FEET

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determined on a case by case basis for on-site sewage disposal systems: boring 1 - elevated sand mound; boring 3 - shallow trench systems utilizing alternating fields, flood dosing or pressure distribution. It was recommended in the report that for each potential residential lot, soil borings be made to determine the optimal location and appropriate system with some lots potentially being unsuitable for any on-site system. The Division of Sanitary Engineering strongly suggested that a central wastewater collection system be connected to the city wastewater treatment facility be the first consideration.

A review of the Dubois County Health Department records show that there is limited documentation on the designed and constructed septic systems for residences on the watershed. Records exist for July of 1979 to September of 1988. Several of these had no backfill inspections to verify construction or location due to a lack of notification to the Dubois County Health Department (pers. comm. Donna Oeding).

Through numerous personal contacts, we determined that extensive underground clay mines are located on the east edge of the lake watershed (Watershed Land Use Map). Clay pits, shaft mines and slope mines were active in this area in the late 1920s through the late 1950s which were operated by the Uhl Pottery Company and the Louisville Pottery Works. The underground mines were approximately 37 feet deep with the clay 5 to 6 feet thick overlain with 1 to 2 feet of coal (pers. comm. C. Gerken). The slope mine located within the eastern section of the watershed had continual problems with groundwater seepage to the extent that a sump was installed to mechanically pump the water out of the mine throughout the working day (pers. comm. C. Gerken). An acid mine seep is located adjacent to this area near the culvert on Old Highway 64 which feeds into the tributary of subwatershed number 2, as shown on Figures 1 and 2. This was identified as acid mine drainage by the State Board of Health in 1975 (208 Water Quality Management Report). It has a distinct orange color and has existed for decades (pers. comm. Max Olinger).

Historically, the watershed land use has not changed since the 1940s, except for the residential development pronounced through the late 1970s and throughout the 1980s. For the most part, recent agricultural practices have changed utilizing the more conservative practices of reduced-till and no-till farming, and to some degree attitudes have changed in regards to the proper use of pesticides and fertilizers (pers. comm. Theron Seemann). The USDA, Soil Conservation Service has conducted extensive soils mapping throughout the lake watershed including the determination of highly erodible soils. As shown on the Huntingburg Lake Soils Map (Appendix), 96 percent of the entire watershed is classified as highly erodible soils. Only the Stendal soil type found along the drainage channels is not classified as highly erodible.

A review of the records of the Indiana Department of Natural Resources, Division of Nature Preserves showed that no threatened, endangered or rare species, no known significant natural area, nor nature preserves are located within the lake's watershed nor any classified within one mile of the watershed.

Throughout the historical records, the information indicates that Huntingburg Lake has had on-going problems with sedimentation, aquatic vegetation, rough fish populations and turbidity while having a watershed that is comprised almost entirely of highly erodible land with significant limitations due to permeability, fragipans, depth to bedrock and slope.

2.2 Field Surveys

The initial field survey of Huntingburg Lake was conducted on August 8, 1989, by Donan Engineering Co., Inc. staff to collect samples providing for the analysis of lake water quality, sediment composition, plankton species and populations, as well as aquatic plant identification. Another survey was conducted on August 21, 1989, during a 2.7 inch/5 hour storm event to collect the lake influent samples and flow data. Watershed land use verification was conducted in mid-August. A final field survey was conducted on September 27, 1989, to collect data on the acid mine seep along the lake's southeastern tributary. For the field and laboratory parameters refer to Tables 2 and 3.

The equipment used during the lake reconnaissance consisted of a Hydrolab Surveyor II, a Martek transmissometer, a Secchi disk, an Eagle depth finder, a Kahlisico column sampler, and Monark boat. The Hydrolab Surveyor II is a multi-probe instrument capable of in-situ measurements of pH, specific conductance, dissolved oxygen, and temperature at any depth up to 250 feet. The Martek transmissometer measures the intensity of light which gives a measure of turbidity. The Secchi disk

TABLE 2.

FIELD AND LABORATORY PARAMETER LIST
HUNTINGBURG LAKE

LAKE POOL

Field:	Laboratory:	Laboratory:
Secchi Disk Reading	Unregulated VOC's List 1:	Unregulated VOC's List 2:
Turbidimeter Reading	Bromobenzene	Ethylene dibromide (EDB)
Temperature	Bromodichloromethane	1,2-Dibromo-
Dissolved Oxygen	Bromoform	3-Chloropropane (DBCP)
pH	Bromomethane	
Specific Conductance	Chlorobenzene	Unregulated VOC's List 3:
Light Transmission	Chlorodibromomethane	Bromochloromethane
	Chloroethane	n-Butylbenzene
	Chloroform	Dichlorodifluoromethane
	Chloromethane	Fluorotrichloromethane
	o-Chlorotoluene	Hexachlorobutadiene
	p-Chlorotoluene	Isopropylbenzene
Laboratory:	Dibromomethane	p-Isopropyltoluene
	m-Dichlorobenzene	Napthalene
Total Suspended Solids	o-Dichlorobenzene	n-Propylbenzene
	trans-1,2-Dichloroethylene	sec-Butylbenzene
Nutrients:	cis-1,2-Dichloroethylene	tert-Butylbenzene
Total Phosphorus	Dichloromethane	1,2,3-Trichlorobenzene
Dissolved Phosphorus	1,1-Dichloroethane	1,2,4-Trichlorobenzene
TKN	1,1-Dichloropropene	1,2,4-Trimethylbenzene
Nitrate	1,2-Dichloropropane	1,3,5-Trimethylbenzene
Ammonia	1,3-Dichloropropane	
	cis-1,3-Dichloropropene	Organic Chemicals:
Bacteria:	trans-1,3-Dichloropropene	Endrin
Fecal coliform	2,2-Dichloropropane	Lindane
Fecal streptococcus	Ethylbenzene	Methoxychlor
	Styrene	Toxaphene
Regulated VOC'S:	1,1,2-Trichloroethane	2,4 D
	1,1,1,2-Tetrachloroethane	2,4,5 TP Silvex
Benzene	1,1,2,2-Tetrachloroethane	Total Trihalomethanes
Carbon Tetrachloride	Tretrachloroethylene	
p-Dichlorobenzene	1,2,3-Trichloropropane	
1,2-Dichloroethane	Toluene	
1,1-Dichloroethylene	p-Xylene	
1,1,1-Trichloroethane	o-Xylene	
Trichloroethylene	m-Xylene	
Vinyl Chloride		

VOC = Volatile Organic Chemical

TABLE 3.

FIELD AND LABORATORY PARAMETER LIST
HUNTINGBURG LAKE

LAKE INFLUENT

Field:	Laboratory:
Temperature	Total Phosphorus
pH	Dissolved Phosphorus
Discharge	TKN
	Nitrate
	Ammonia
	Total Suspended Solids
	Fecal Coliform
	Fecal Streptococcus

ACID MINE SEEP

Field:	Laboratory:
Temperature ^{o}C	pH
pH	Specific Conductance
Discharge	Total Alkalinity
	Total Acidity
	Dissolved Solids
	Suspended Solids
	Total Iron
	Total Manganese
	Chloride
	Sulfate
	Fecal Coliform
	Fecal Streptococcus

SEDIMENT CORES

Laboratory:

Total Solids

EP Toxicity Test: Metals
Herbicides and Pesticides

Nutrients: Total Phosphorus
Dissolved Phosphorus
TKN
Nitrate
Ammonia

was used to measure the transparency of the lake. The Eagle depth finder was used to sound inlets for sediment deposition. The Kahlisico column sampler is used to collect a sample of water at any given depth up to 500 feet. The Monark boat, which housed all the equipment, is a specially designed boat used only for lake sampling projects.

In-situ water quality parameters were measured at the lake pool station, HL-1 (Figure 5). In-situ profile measurements of temperature, dissolved oxygen, pH, turbidity, conductivity and light-transmisivity were made at five-foot intervals to immediately above the sediment surface. Secchi disk depth was recorded, and plankton samples were obtained. For a listing of the methods and references, see Table 4. Water samples were collected at three, twelve, and eighteen feet using a Van Dorn sampler. The samples were composited before analysis.

Fecal coliform samples initially were taken at lake stations HL-1, HL-3/4, and HL-10. Resampling for fecal coliform and fecal streptococcus occurred at stations HL-1, HL-10, HL-11, and at the acid mine seep (Figure 5).

Sediment samples were taken at HL-3/4 and at HL-5/6. It was determined that a lake sediment profile would not be necessary at this time due to the limited sedimentation of the lake.

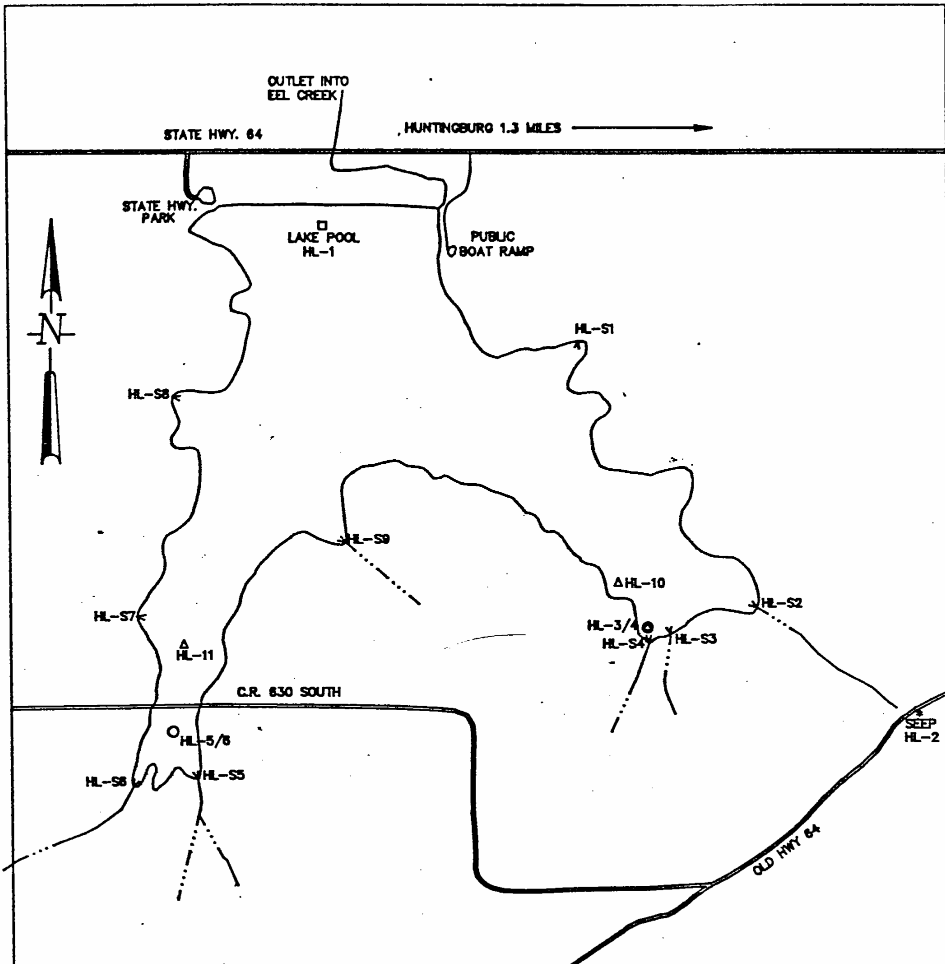

FIGURE 5.
MONITORING POINTS ON HUNTINGBURG LAKE

LEGEND

- □ LAKE POOL
- △ LOW FLOW
- < INFLUENT
- o SEDIMENT

SCALE

0 1000

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TABLE 4.

CHEMICAL PARAMETERS AND ANALYTICAL METHODS

PARAMETER	INSTRUMENT OR METHOD	REFERENCE SECTION
Total Phosphorus	Colorimetric	424 C III
Soluble Phosphorus	Colorimetric	424 C III
Nitrate	Ion Chromatography	429
Ammonia	Specific Ion Electrode	417 E
Total Kjeldahl Nitrogen	Digestion and Specific Ion Electrode	420 B
Total Suspended Solids	Gravimetric	209 C
Fecal Coliform	Incubation, Visual Count	909 A
Fecal Streptococcus	Incubation, Visual Count	910

Reference Source: Standard Methods 16th Edition

A visual aquatic plant survey of Huntingburg Lake was conducted with photographic documentation (Appendix). Plant species were identified and their frequency of distribution noted.

Watershed land use information was collected through several means. Aerial photographs were supplied by the City of Huntingburg dated 3-2-87, and by the USDA Agricultural Stabilization and Conservation Service dated 8-27-66. A field survey verified current land usage and new residential development. Contacts were made in the attempt to acquire information regarding livestock populations and agricultural practices, history of the clay mines along the eastern edge of the watershed, and information on golf course maintenance and use of fertilizers, pesticides and herbicides. All the pertinent information was compiled into the Huntingburg Lake Watershed Map (Appendix).

2.3 Results

2.3.1. Water Quality

In-situ water quality results are presented in Table 5 and Figures 6 and 7. These data illustrate that Huntingburg Lake was thermally stratified with the thermocline at approximately 12 feet. Dissolved oxygen concentrations were below saturation throughout the water column except at the air-water interface. The hypolimnetic waters showed increased levels of turbidity and conductivity. Light transmissivity was observed to be low in the upper waters and decrease through the water column.

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FIGURE 6.

Selected Water Quality Parameters vs. Sampling Depth at Huntingburg Lake Station HL1

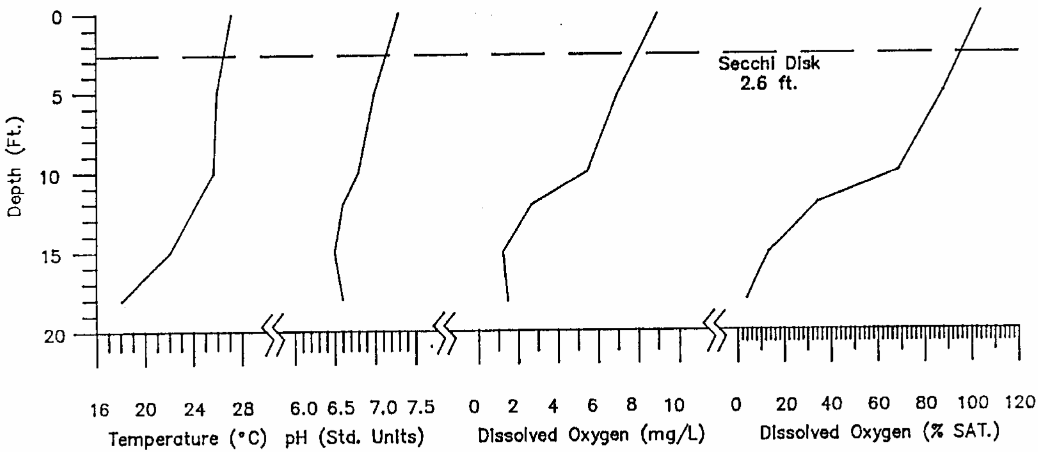

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FIGURE 7.

Selected Water Quality Parameters vs. Sampling Depth at Huntingburg Lake Station HL1

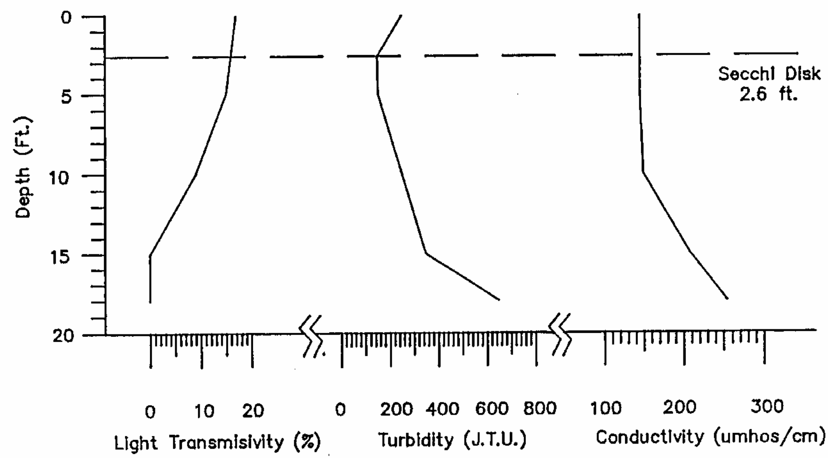


TABLE 5.

HUNTINGBURG LAKE IN-SITU WATER QUALITY RESULTS

AUGUST 8, 1989.

SAMPLE ID	TIME	DEPTH	pH	TEMP °C	DO mg/L	SAT.	L.T.	TURBID. (JTU)	CONDUCT. (umhos/cm)
HL-1	1350	0	7.3	27.3	9.0	114%	17%	250	144
		5	7.0	26.0	7.0	88%	15%	150	144
		10	6.8	25.7	5.5	69%	9%	250	146
		12	6.6	25.1	2.8	34%	6%	200	153
		15	6.5	22.0	1.1	13%	0%	350	209
		18	6.6	18.1	1.4	2%	0%	650	253

DO = Dissolved Oxygen
SAT. = DO % Saturation
L.T. = Light Transmisivity

The composited lake pool chemical analysis is given in Table 6. Ammonia and total Kjeldahl nitrogen were present in high concentrations. The lake pool station did not have any detectable Volatile Organic Compounds (VOCs) present (Lab Analysis, Appendix).

TABLE 6. HUNTINGBURG LAKE WATER QUALITY ANALYSIS

DATE	TIME	NH_3-N mg/L	NO_3-N mg/L	TKN mg/L	DP mg/L	TP mg/L	TSS mg/L
08 Aug.89	1350	1.15	<0.05	2.48	0.05	0.05	36

NH_3-N = Ammonia as Nitrogen
NO_3-N = Nitrate as Nitrogen
TKN = Total Kjeldahl Nitrogen
DP = Dissolved Phosphorus
TP = Total Phosphorus
TSS = Total Suspended Solids

The influent data are presented in Table 7. The data show that there are significant concentrations of ammonia in the influent from subwatersheds 2, 3, 4 and 8 and excessive concentrations at subwatershed 7 at 1.27 mg/L (See Subwatershed Definition Map in the Appendix). There are also significant concentrations of nitrate in the influent from subwatersheds 2, 8, and 9 and excessive concentrations at subwatersheds 3, 4, 5 and 6.

TABLE 7. HUNTINGBURG LAKE INFLUENT WATER QUALITY ANALYSIS

SAMPLED ID	DATE	TIME	pH	NH_3-N mg/L	NO_3-N mg/L	TKN mg/L	DP mg/L	TP mg/L	TSS mg/L
HL-S1	21 Aug. 89	1145	6.3	0.14	0.05	2.40	0.19	0.25	40
HL-S2	21 Aug. 89	0905	6.2	0.31	0.39	1.40	0.03	0.23	359
HL-S3	21 Aug. 89	0920	6.8	0.58	0.84	3.50	2.20	2.50	174
HL-S4	21 Aug. 89	0920	6.8	0.46	0.96	3.90	2.30	2.60	96
HL-S5	21 Aug. 89	0940	6.5	0.24	0.83	2.30	0.14	0.31	144
HL-S6	21 Aug. 89	0945	6.4	0.29	0.80	2.60	0.13	0.34	164
HL-S7	21 Aug. 89	0955	6.8	1.27	<0.05	5.50	0.12	0.41	51
HL-S8	21 Aug. 89	1010	8.0	0.32	0.38	1.80	0.09	0.30	314
HL-S9	21 Aug. 89	0930	---	0.24	0.35	2.10	0.55	0.63	14

NH_3-N = Ammonia as Nitrogen
NO_3-N = Nitrate as Nitrogen
TKN = Total Kjeldahl Nitrogen
DP = Dissolved Phosphorus
TP = Total Phosphorus
TSS = Total Suspended Solids
--- = Not Obtained

Total Kjeldahl nitrogen was present in significant concentrations at all the influent stations, but of particular note are the nitrogen levels at subwatersheds 3, 4 and 7 where concentrations exceeded 3.0 mg/L. Significant quantities of dissolved phosphorus and total phosphorus were measured at all the subwatershed influent points, particularly subwatersheds 3 and 4 with measured concentrations exceeding 2.0 mg/L for both parameters. Total suspended solids had a range of 14 to 359 mg/L, and were generally not associated with significant nutrient concentrations, indicating nutrients were in water soluble forms.

Fecal bacteria counts show a contamination of fecal coliform at all lake points monitored (Table 8) with significant counts at the lake pool station, in the east lake at subwatersheds 3 and 4, and in the west leg near subwatershed 7. Fecal streptococcus was in deficient quantities at most stations to determine a statistically valid ratio. Station HL-11, reflecting subwatersheds 5, 6 and 7, did have sufficient counts of fecal strep to calculate a ratio of 16.4, indicating pollution derived from human wastes (Bureau of Water Hygiene, EPA).

2.3.2. Aquatic Vegetation

Plankton counts at the lake pool show that at the time of the survey Huntingburg Lake was heavily populated by

TABLE 8. HUNTINGBURG LAKE FECAL BACTERIAL RESULTS

SAMPLE ID	DATE	FECAL COLIFORM C/100 ml	FECAL STREP C/100 ml	RATIO FC/FS
HL-1	08 Aug 89	280	---	---
HL-1	27 Sept 89	1500	10	N/A
HL-10	08 Aug 89	630	---	---
HL-10	27 Sept 89	1400	<1	N/A
HL-11	27 Sept 89	410	25	16.4

TABLE 8 (Cont'd)
AVERAGE INDICATOR DENSITY PER GRAM OF FECES

SOURCE	FECAL COLIFORM MILLION	FECAL STREPTOCOCCI MILLION	RATIO FC/FS
Human	13.0	3.0	4.4
Sheep	16.0	38.0	0.4
Cow	0.23	1.3	0.2
Turkey	0.29	2.8	0.1
Pig	3.3	84.0	0.04

(Data from Bureau of Water Hygiene, Environmental Protection Agency, Cincinnati, Ohio.)

FC/FS 4.0 - Ratio greater than or equal to 4 indicates pollution derived from human wastes.

FC/FS 2-4 - Ratio between 2 and four suggests a predominance of human wastes in mixed pollution.

FC/FS 0.7 - Ratio less than or equal to 0.7 indicates pollution derived from livestock or poultry.

FC/FS 0.7-1.0 - Ratio between 0.7 and 1.0 suggests a predominance of livestock or poultry wastes in mixed pollution.

flagellate algae (Chlamydomonas and Gonium) and by non-filamentous green algae (Ankistrodesmus and Scenedesmus). Limited macrophytes occurred along the lakeshore and to a depth of less than one foot. Water willow (Justicia american) was present along almost the entire shoreline except for steep banks and high energy areas. Other less significant populations on parts of the shoreline were buttonbush (Cephalanthus occidentalis), and cattail (Typha sp.). No species of naiads (Najas spp.) were observed to be present, though naiads had been reported as a problem submerged aquatic in the upper and middle lakes (Fish Survey, 1964).

2.3.3. Sediment

As shown in Table 9, at location HL-3/4 in the upper lake, sediments have a high concentration of total Kjeldahl nitrogen (TKN) at 1010 mg/Kg, with a moderate ammonia concentration. This is common since most of the nitrogen is expected to be bound as organic nitrogen in sediments. Nitrate was below the detection limit. Dissolved phosphorus is representative of the amount of phosphorus that was present in the porewater in the sediments. The dissolved phosphorus was found to be less than 0.5 mg/Kg. The final units of mg/Kg are defined as milligrams of phosphorus as centrifuged from kilograms of sediment. Total Phosphorus was reported at 260 mg/Kg. At location HL-5/6 sediments also have a high TKN concentration at 817.8 mg/Kg. Plant available ammonia (298 mg/Kg), nitrate (2.53 mg/Kg) and dissolved phosphorus (9.5 mg/Kg) were present in significant concentrations. Total Phosphorus was present at 319.6 mg/Kg. No detectable concentrations of metals, herbicides, or pesticides were present in the sediments except for lead (See lab sheet in Appendix). Lead was present at 0.05 mg/L at HL-5/6 and at 0.06 mg/L at HL-3/4 with the detection limit at 0.05 mg/L.

TABLE 9. HUNTINGBURG LAKE SEDIMENT DATA

SAMPLE ID	DATE	NH_3-N (mg/Kg)	NO_3-N mg/Kg	TKN mg/Kg	DP mg/Kg	TP mg/Kg	TS
HL-3/4	08 Aug. 89	22.3	<0.05	1010.0	<0.05	260.0	74%
HL-5/6	27 Aug. 89	29.8	2.53	817.8	9.5	319.6	58.3%

NH_3N = Ammonia as Nitrogen
ND_3N = Nitrate as Nitrogen
TKN = Total Kjeldahl Nitrogen
DP = Dissolved Phosphorus
TP = Total Phosphorus
TS = Total Solids

2.3.4. Watershed

The watershed of Huntingburg Lake is predominantly agricultural as shown in Table 10 and on the Huntingburg Lake Watershed Land Use Map (Appendix). Cropland comprises 23 percent of the watershed with pasture comprising 25 percent for a total agricultural land base of 48 percent. Forest totals 36 percent, though it is noted that grazing of cattle occurs within some areas that are forested along the southern extents

TABLE 10. HUNTINGBURG LAKE WATERSHED ANALYSIS IN ACRES

WATERSHED SECTION	RESIDENTIAL	CROPLAND	PASTURE	FOREST	WATER	GOLF COURSE	ROAD	TOTAL
1	1.1	---	9.3	8.8	---	12.5	---	31.7
1A	2.0	---	10.9	5.3	---	---	---	18.2
1B	---	---	---	10.4	---	11.3	---	21.7
1C	---	---	---	0.7	---	25.8	---	26.5
2	15.2	51.6	16.0	61.2	2.5	7.5	1.1	155.1
2A	1.0	1.0	---	3.8	0.3	12.0	0.1	18.2
3	7.4	4.2	89.8	21.5	---	---	2.9	125.8
3A	---	---	2.0	1.4	---	---	---	3.4
4	6.4	---	12.9	5.2	0.3	---	0.3	25.1
4A	5.0	12.5	1.7	15.7	0.2	---	0.7	35.8
5	10.4	5.5	41.2	70.6	4.7	---	1.6	134.0
5A	3.0	---	4.9	3.1	---	---	---	11.0
6	13.7	89.2	63.7	58.7	1.2	---	1.7	228.2
6A	---	2.9	1.7	2.6	---	---	---	7.2
7	4.6	7.8	1.1	12.6	2.6	---	---	28.7
7A	1.6	---	2.0	1.9	---	---	1.1	6.6
7B	---	9.6	---	10.1	---	---	---	19.7
8	---	19.0	---	15.5	0.3	---	---	34.8
8A	---	14.7	---	11.1	---	---	---	25.8
8B	2.4	2.3	2.0	17.8	---	---	---	24.5
9	1.0	7.2	---	7.0	0.2	---	---	15.4
9A	---	0.3	---	12.8	---	---	---	13.1
9B	1.4	14.9	---	14.9	---	---	1.8	33.0
TOTAL	76.2	242.7	259.2	372.7	12.3	69.1	11.3	1043.5
PERCENTAGES	7%	23%	25%	36%	1%	7%	1%	100%

of the watershed. The country club and golf course comprise 7 percent of the watershed, with residential areas also totalling 7 percent. The remaining land uses are water (1 percent) and road (1 percent). Table 11 illustrates the subwatersheds that were monitored for nutrient loading and sedimentation during a storm event. Surface runoff originating from these monitored subwatersheds accounts for 75 percent of the total lake watershed area.

Examination of the Huntingburg Lake Soils Map (Appendix) revealed that potentially highly erodible land (HEL soils) occurs within 96 percent of the lake watershed. Non-HEL soils (Stendal) occur only along the lake tributaries, 4 percent of the total watershed. As shown in Table 12, the agricultural land uses account for 92 percent of the HEL soils.

The field survey and a check of the plat book indicated that at some points the shoreline owned by the city is at a minimum with residential development in close proximity to the lake and its tributaries (Land Use Map, Appendix). Many of these residences were constructed prior to 1979 when the Dubois County Health Department began maintaining detailed records and conducting septic inspections during construction. No known inspections of septic systems using tracer dyes have been conducted on the lake watershed to date.

The acid mine seep on subwatershed 2 was calculated to have a flow of 0.028 cubic feet per second (cfs) totalling approximately 18,096 gallons per day. The analysis of various parameters are shown in Table 13.

The apparent presence of alkaline materials within the clay shafts and/or overburden has partially neutralized the pH to 6.6, with most acid mine seeps having a pH range of 2.0 to 4.5 (USDA, Forest Service). The iron, manganese, and sulfate concentrations are high, but not excessive when compared to other acid mine seeps. However, suggested standard limits for chemical parameters in drinking water are: iron @ 0.30 mg/L, manganese @ 0.05 mg/L, sulfate @ 350 mg/L, and total dissolved solids @ 500 mg/L (USFS, 1986). Other than total dissolved solids, these parameters were not monitored at the lake pool

TABLE 11.
HUNTINGBURG LAKE MONITORED SUBWATERSHED ANALYSIS IN ACRES

WATERSHED SECTION	RESIDENTIAL	CROPLAND	PASTURE	FOREST	WATER	GOLF COURSE	ROAD	TOTAL
1	1.1	---	9.3	8.8	---	12.5	---	31.7
2	15.2	51.6	16.0	61.2	2.5	7.5	1.1	155.1
3	7.4	4.2	89.8	21.5	---	---	2.9	125.8
4	6.4	---	12.9	5.0	0.3	---	0.3	24.9
5	10.4	5.5	41.2	70.6	4.7	---	1.6	134.0
6	13.7	89.2	62.6	58.7	1.2	---	1.7	227.1
7	4.6	7.8	1.1	12.6	2.6	---	---	28.7
8	---	19.0	---	15.5	0.3	---	---	34.8
9	1.0	7.2	---	7.0	0.2	---	---	15.4
TOTAL	59.8	184.5	232.9	260.9	11.8	20.0	7.6	777.5
PERCENTAGE	6%	18%	22%	25%	1%	2%	1%	75%

TABLE 12.
HIGHLY ERODIBLE LAND ANALYSIS BY MONITORED SUBWATERSHED

SUBWATERSHED	AGRICULTURAL LAND USE ACRES	HEL SOILS	NON-HEL SOILS
1	9.3	100%	0%
2	67.6	95%	5%
3	95.9	89%	11%
4	12.9	82%	18%
5	46.7	80%	20%
6	151.8	90%	10%
7	8.9	89%	11%
8	19.0	100%	0%
9	7.2	100%	0%
TOTALS	419.3	92% AV	8% AV

station to evaluate the lake's diluting effect. The specific conductance and dissolved solids could be keyed to dissolved clay in the water. There is fecal bacterial contamination of the waters feeding into the seep as shown by a fecal streptococcus count of 3000 C/100 ml. The ratio of 0.005 indicates that contamination is from a livestock or animal source and not a human source (EPA, Bureau of Water Hygiene).

TABLE 13. HUNTINGBURG LAKE ACID MINE SEEP ANALYSIS

PARAMETER	
pH (field):	6.6
pH (lab):	6.5
Temperature:	$13^{o}C$
Specific Conductance:	1096 umhos
Total Alkalinity:	66(mg/L)
Total Acidity:	64(mg/L)
Dissolved Solids:	768(mg/L)
Suspended Solids:	4(mg/L)
Total Iron:	27.9(mg/L)
Total Manganese:	8.12(mg/L)
Chloride:	3.1(mg/L)
Sulfate:	330(mg/L)
Fecal Coliform:	16 C/100 ml
Fecal Streptococcus:	3000 C/100 ml
FC/FS:	0.005

SECTION 3. DISCUSSION

3.1 Eutrophication Index

The Indiana Lake Classification System and Management Plan (IDEM, 1986) provides a eutrophication index system developed by Harold BonHomme to assign points for various lake trophic parameters. The index utilizes the trophic parameter information gathered during the field surveys. A Eutrophication Index of 41 for Huntingburg Lake was calculated using 1989 data and is displayed in Table 14. A Eutrophication Index of 29 for Huntingburg Lake was calculated using 1990 data and is displayed in Table 17.

The Eutrophication Index for Huntingburg Lake was originally calculated at 18 during the summer months of 1975 defining it as a Class One lake. Government or private protection of the lake and its watershed as well as restriction of recreational use and shoreland development were the recommended primary management techniques to maintain the lake's quality.

TABLE 14. ISBH LAKE EUTROPHICATION INDEX
HUNTINGBURG LAKE - AUGUST 8, 1989

Parameter and Range		Range Observed	Eutrophy Points
I.	Total Phosphorus (ppm)		
	A. At least 0.03		1
	B. 0.04 to 0.05	0.05	>2<
	C. 0.06 to 0.19		3
	D. 0.2 to 0.99		4
	E. 1.0 or more		5
II.	Soluble Phosphorus (ppm)		
	A. At least 0.03		1
	B. 0.04 to 0.05	0.05	>2<
	C. 0.06 to 0.19		3
	D. 0.2 to 0.99		4
	E. 1.0 or more		5
III.	Organic Nitrogen (ppm)		
	A. At least 0.5		1
	B. 0.6 to 0.8		2
	C. 0.9 to 1.9	1.33	>3<
	D. 2.0 or more		4
IV.	Nitrate (ppm)		
	A. At least 0.3	<0.05	1
	B. 0.4 to 0.8		2
	C. 0.9 to 1.9		3
	D. 2.0 or more		4
V.	Ammonia (ppm)		
	A. At least 0.3		1
	B. 0.4 to 0.5		2
	C. 0.6 to 0.9		3
	D. 1.0 or more	1.15	>4<
VI.	Dissolved Oxygen (Percent Saturation at 5 ft. from surface)		
	A. 114% or less	88%	>0<
	B. 115% to 119%		1
	C. 120% to 129%		2
	D. 130% to 149%		3
	E. 150% or more		4

TABLE 14. ISBH LAKE EUTROPHICATION INDEX (CON'T.)
HUNTINGBURG LAKE - AUGUST 8, 1989

Parameter and Range	Range Observed	Eutrophy Points
VII. Dissolved Oxygen		
(Percent of water column with D.O. $\geq$ 0.1 ppm)		
A. 28% or less		4
B. 29% to 49%		3
C. 50% to 65%		2
D. 66% to 75%		1
E. 76% to 100%	100%	>0<
VIII. Light Penetration		
Secchi Disc		
A. Five feet or under	2.6 ft.	>6<
IX. Light Transmission		
(Percent at 3 ft.)		
A. 0 to 30%	17%	>4<
B. 31% to 50%		3
C. 51% to 70%		2
D. 71% and up		0
X. Total Plankton per ml:		
(Vertical tow from 5 ft.)		
A. Less than 500 ml		0
B. 500 to 1,000/ml		1
C. 1,000 to 2,000/ml		2
D. 2,000 to 3,000/ml		3
E. 3,000 to 6,000/ml		4
F. 6,000 to 10,000/ml		5
G. More than 10,000/ml	20,000	>10<
H. Blue-green dominance		5 additional points
(Vertical tow from 5 ft. including thermocline)		
A. Less than 1,000/ml		0
B. 1,000 to 2,000/ml		1
C. 2,000 to 5,000/ml		2
D. 5,000 to 10,000/ml		3
E. 10,000 to 20,000/ml		4
F. 20,000 to 30,000/ml		5
G. 30,000 or more	50,000	>10<
H. Blue-green dominance		5 additional points
I. Populations of 100,000 or more		5 additional points
EUTROPHICATION INDEX		41

Donan Engineering believed it prudent to verify the unusually high plankton counts that were recorded on August 8, 1989 by resampling the plankton and adjusting, if necessary, the index values of organisms per liter. Donan Engineering also wanted to obtain separate epilimnetic (upper waters) and hypolimnetic (lower waters) nutrient concentrations as opposed to one composite number. Therefore, Huntingburg Lake was resampled for all parameters that are used in the Eutrophication Index at Donan Engineering's expense on August 24, 1990. All chemical, physical, and biological data sheets can be referenced in the Appendix. A summary of the epilimnetic and hypolimnetic water chemistry is presented in Table 15.

TABLE 15. 1990 HUNTINGBURG LAKE WATER QUALITY ANALYSIS

DATE	DEPTH	TIME	NH_3-N mg/L	NO_3-N mg/L	TKN mg/L	Org-N mg/L	SRP mg/L	TP mg/L
24 Aug.90	3 ft.	1330	0.03	<0.1	0.58	0.55	<0.01	0.01
24 Aug.90	18 ft.	1430	3.77	<0.1	3.85	0.08	<0.01	0.06
		AVERAGE	1.90	<0.1	2.22	0.32	<0.01	0.04

NH_3-N = Ammonia as Nitrogen
NO_3-N = Nitrate as Nitrogen
TKN = Total Kjeldahl Nitrogen
SRP = Soluble Reactive Phosphorus
TP = Total Phosphorus
ORG-N = Organic Nitrogen

Table 16 displays the phytoplankton and zooplankton analysis for each of two tows, five feet to the surface, and five feet through the thermocline.

TABLE 16. HUNTINGBURG LAKE PLANKTON ANALYSIS
AUGUST 24, 1990

5.0 FOOT TO SURFACE DEPTH

ALGAE	TOTAL # PER LITER
Cyanophyta	
Anabaena	177
Oscillatoria	7,084
Coelospharerium	885
Chlorophyta	
Pediastrum	539
Ulothrix	177
Protozoa	
Difflugia	177
Chrysophyta - Bacillasiophyceae	
Synedra	354
Pyrrophyta	
Ceratium	177
Rotifera	
Keratella	354
Chromogaster	177
Polyarthra	354
Arthropoda - Crustacea - Cladocera	
Daphnia	177
Bosmina	177
Arthropoda - Crustacea - Copepoda	
Calanoid	177
Cyclopoid	177
Nauplii	354
Total =	11,517

5.0 FOOT THROUGH THERMOCLINE 12 FOOT TO 7 FOOT

ALGAE	TOTAL # PER LITER
Cyanophyta	
Oscillatoria	362
Aphanizomenon	181
Protozoa	
Difflugia	181
Total =	724

* These data were collected using a 63 micron net mesh closing net. The samples were quantified using a 1-ml Sedgwick-Rafter counting cell.

The following eutrophication index is obtained when using the 1990 data.

TABLE 17. ISBH LAKE EUTROPHICATION INDEX
HUNTINGBURG LAKE - AUGUST 24, 1990

Parameter and Range	Range Observed	Eutrophy Points
I. Total Phosphorus (ppm)		
A. At least 0.03	0.04	>1<
B. 0.04 to 0.05		2
C. 0.06 to 0.19		3
D. 0.2 to 0.99		4
E. 1.0 or more		5
II. Soluble Phosphorus (ppm)		
A. At least 0.03	<0.01	1
B. 0.04 to 0.05		2
C. 0.06 to 0.19		3
D. 0.2 to 0.99		4
E. 1.0 or more		5
III. Organic Nitrogen (ppm)		
A. At least 0.5	0.32	1
B. 0.6 to 0.8		2
C. 0.9 to 1.9		3
D. 2.0 or more		4
IV. Nitrate (ppm)		
A. At least 0.3	<0.1	1
B. 0.4 to 0.8		2
C. 0.9 to 1.9		3
D. 2.0 or more		4
V. Ammonia (ppm)		
A. At least 0.3		1
B. 0.4 to 0.5		2
C. 0.6 to 0.9		3
D. 1.0 or more	1.90	>4<
VI. Dissolved Oxygen (Percent Saturation at 5 ft. from surface)		
A. 114% or less	89%	>0<
B. 115% to 119%		1
C. 120% to 129%		2
D. 130% to 149%		3
E. 150% or more		4
VII. Dissolved Oxygen (Percent of water column with D.O. $\geq$ 0.1 ppm)		
A. 28% or less		4
B. 29% to 49%		3
C. 50% to 65%	55%	>2<
D. 66% to 75%		1
E. 76% to 100%		0
VIII. Light Penetration Secchi Disc		
A. Five feet or under	2.5 ft.	>6<

TABLE 17. ISBH LAKE EUTROPHICATION INDEX (CON'T.)
HUNTINGBURG LAKE - AUGUST 24, 1990

Parameter and Range		Range Observed	Eutrophy Points
IX.	Light Transmission (Percent at 3 ft.)		
	A. 0 to 30%	15%	>4<
	B. 31% to 50%		3
	C. 51% to 70%		2
	D. 71% and up		0
X.	Total Plankton per ml: (Vertical tow from 5 ft. to surface)		
	A. Less than 4700/L		0
	B. 4,701 to 9,500/L		1
	C. 9,501 to 19,000/L	11,517	>2<
	D. 19,001 to 28,000/L		3
	E. 28,001 to 57,000/L		4
	F. 57,001 to 95,000/L		5
	G. More than 95,000/L		10
	H. Blue-green dominance		>5 additional points<
	(Vertical tow of 5 ft. through thermocline)		
	A. Less than 9,500/L	724	>0<
	B. 9,501 to 19,000/L		1
	C. 19,001 to 47,000/L		2
	D. 47,001 to 95,000/L		3
	E. 95,001 to 190,000/L		4
	F. 190,001 to 285,000/L		5
	G. More than 285,000/L		10
	H. Blue-green dominance		>5 additional points<
	EUTROPHICATION INDEX		29

Both eutrophication index values of 41 and 29 reclassify Huntingburg Lake as a Class Two lake. These values substantiate the concerns the City of Huntingburg has regarding the increasing eutrophic conditions of their primary water facility as the city's population and industry base increases.

3.2 Hydrologic Conditions

Of particular interest concerning the hydrology of Huntingburg Lake is the hydraulic residence time or retention time. The retention time is the length of time required for the total volume of the lake to be replaced. This can be estimated from mean annual runoff, watershed area and lake volume.

The average rainfall for the Huntingburg area is approximately 45 inches (National Oceanic and Atmospheric Administration - Climatological Data). The annual average runoff determined for Dubois County is 16.0 inches (Gebert, Graczy, and Krug, 1985 - Map included in the Appendix). Thus, the 1043.5 acre watershed would contribute 1391.3 acre-feet of water per year. The lake would receive 551 acre-feet of rainfall directly. The lake would lose approximately 350.5 acre-feet of water per year due to evaporation from the lake surface (IDNR Division of Water - pers. comm. Steven L. Hobson). The seep on the southeast side of the watershed generates 20.3 acre-feet of water per year as well. This combines for an average annual net inflow of 1612.4 acre-feet or 525,366,357 gallons per year. The average pumpage from the lake is approximately 400,000,000 gallons per year. The approximated average lake volume is 530,000,000 gallons. The lake's retention time calculates out to be approximately one year. This is the average time it would take for the lake water volume to be replaced completely assuming normal average rainfall.

3.3 Water Quality

Analysis of the 1989 lake pool water quality indicates that organic nitrogen was present in high concentrations at 1.33 mg/l, as well as ammonia at 1.15 mg/l. Phosphorus was at moderately low concentrations in the lake pool sample. Soluble phosphorus and total phosphorus were both at 0.05 mg/l. It is worthy to note that these are average values obtained from compositing water samples from three separate depths, 5 feet, 12.5 feet, and 17 feet.

Analysis of the 1990 lake pool water quality indicates that the nutrients were depleted in the epilimnetic waters. The nutrients were also low in the hypolimnion except for ammonia which was present at 3.77 mg/L. The TKN value represents all forms of nitrogen in a negative three oxidation state. Therefore, the TKN value is high due to the high ammonia concentration.

Examination of the influent water quality points to subwatersheds 3 and 4 (See Subwatershed Definition Map in the Appendix) for significant sources of total Kjeldahl nitrogen (3.70 mg/l average), dissolved phosphorous (2.25 mg/l average) and total phosphorous (2.55 mg/l average). These subwatersheds, along with subwatershed 4A, are also a contributing source of fecal coliform contamination at lake station HL-10 with counts of 630 C/100 ml on August 8 and 1400 C/100 ml on September 27, 1989. Approximately nine residences are located within this area of the watershed with mostly forest and pasture comprising the remaining acreage. However, cattle graze in those pasture areas, and have access to streams directly feeding the lake.

Further examination also points to subwatersheds 5 and 6 as sources of high levels of total Kjeldahl nitrogen with an average of 2.45 mg/l. Subwatershed 7 influent into the lake has high levels of ammonia (1.27 mg/l) and total Kjeldahl nitrogen (5.50 mg/l), though the phosphorous levels were moderate (0.12 mg/l and 0.41 mg/l). In the west leg of the lake, fecal coliform contamination is evident at lake station HL-11 with a count of 410 C/100 ml, as well as fecal streptococcus at 25 C/100 ml. Approximately 17 residences lie within these subwatersheds, seven of which are in close proximity to the lake.

Primary attention should be devoted to subwatersheds 3, 4, and 7 since they display the highest influent nutrient concentrations and fecal coliform counts.

All of these subwatersheds exhibiting nutrient loading to the lake are in areas evaluated to be unsuitable for septic tank systems by the 1987, Indiana State Board of Health Soil Evaluation Report, and have livestock in the pasture areas.

3.4 Watershed Land Use

With agriculture as the predominant land use, it is discerned to be a significant source of nutrients and sediment to the lake. The soils are primarily highly erodible soils, with conservation tillage methods implemented to a limited degree. In addition, livestock have access to the tributaries feeding into the lake. This contributes to stream bank erosion and potential contamination as well as nutrient loading from livestock waste directly entering the stream channel. This problem of stream channel contamination could be rectified by simply fencing off the grazing areas for livestock from the stream channel areas. The grazing of the woods along these stream banks is also a detrimental management practice and should be discouraged.

The country club and golf course were not found to be significant sources of nutrients or contaminants. The country club has a septic system that flows to the east out of the watershed. The golf course currently uses minimal fertilizers and negligible amounts of pesticides and herbicides.

The acid mine seep was found to be a point source of contaminants, with the concentrations of iron, manganese, sulfates and dissolved solids significant. The source of animal wastes contaminating the seep, as demonstrated by the fecal strep count of 3000 C/100 ml, is not known. It is suspected that manure from horses and/or other animals on the eastern edge of the watershed may be infiltrating into the abandoned clay shafts contaminating the water in these shafts and the associated seepage. The Indiana Department of Natural Resources, Division of Reclamation is now aware of these abandoned clay mines and the associated acid mine drainage. The Division of Reclamation does not find this to be a priority relative to other abandoned mined lands. Remediation measures might include the development of a wetland, or the diversion of this seepage out of the watershed.

The residential areas are also a significant source of nutrient loading into the lake. The septic effluent from households will contain not only excreta and ground garbage, but also laundry and other cleaning wastes. A septic system may eventually saturate the soil of the septic field into which the wastewater is discharged. Consequently, the groundwater causes a diffuse discharge of nutrients from the shoreline into the lake (IDEM, 1986). As stated in The Indiana State Board of Health's report dated December 29, 1987, soil conditions on the vast majority of the watershed acreage are not suitable for any on-site sewage disposal system due to low permeability, shallow soils and/or slopes exceeding 12 percent. Though not all the residences at this time may be contributing sources of pollutants, the very nature of septic systems and the inherent characteristics of the watershed establish the foundation for problems relative to septic contamination and added nutrient loading into the lake.

3.5 Aquatic Vegetation and Fish Populations

The phytoplankton populations are the result of nutrient loading into the lake supplying nitrogen and phosphorous for plant growth and reproduction. This is also true for the macrophytes, namely water willow, along most of the shoreline.

Due to the lake being the primary water source for the City of Huntingburg, chemical control of the aquatic vegetation is not considered to be an alternative. On October 31, 1988, the lake was 6.7 feet below pool level. Naiads, previously a nuisance submerged aquatic in the upper and middle lakes, have been repressed, assumedly from this drawdown. This decrease in the water level would have exposed the plants to heat desiccation. The water willow population was apparently unaffected or decreased only to a slight degree.

The aquatic vegetation problems are compounded and directly related to the fisheries problems. A simplified comparison of the complex aquatic food chain is shown as Figure 8. Fish management reports state that Huntingburg Lake has a small predator population, a large stunted panfish and gizzard shad population and a limited, but present, carp population. The stunted panfish and gizzard shad feed on zooplankton in the lake. These zooplankton are the biological predator on the phytoplankton (algae) populations. The turbidity of the water increased by the bottom-feeding carp, the extensive vegetation of the shoreline by waterwillow, and the small predator population enables the stunted panfish and shad populations to continue to survive and overgraze the zooplankton. Thus, the algae populations are not adequetly grazed, limited only by nutrients and light penetration of the water. The stocking of saugeye as a predator species that hunts by smell rather than by site should follow the current plans of the Division of Fish and Wildlife with success of establishment a priority.

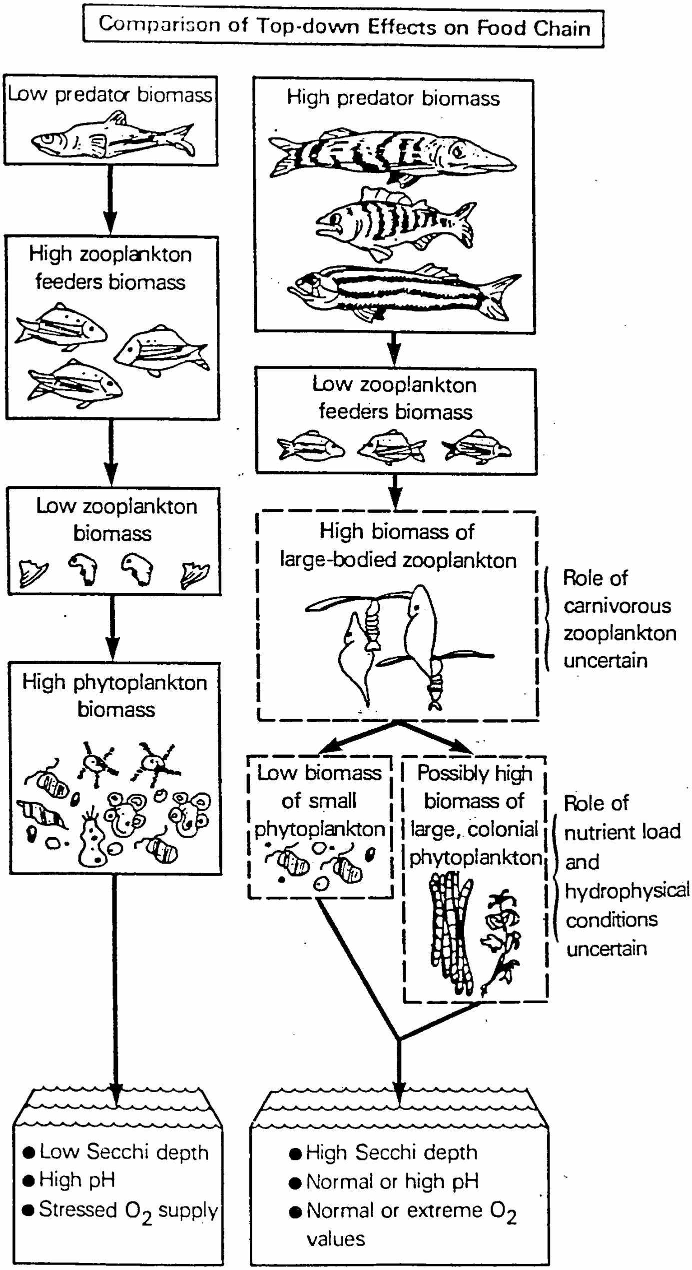


FIGURE 8. AQUATIC FOOD CHAINS

3.6 Computer Modeling

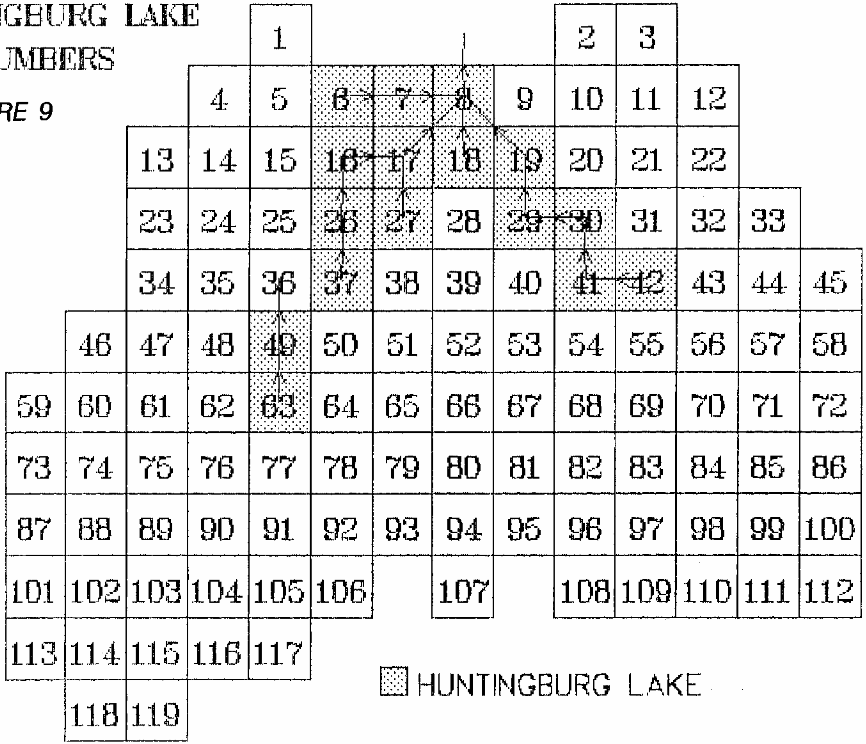
The program used for modeling sediment and nutrient loading into Huntingburg Lake was the Agricultural Non-Point Source Pollution Model (AGNPS). AGNPS was developed by R.A. Young and C.A. Onstad at the USDA North Central Soil Conservation Research Laboratory in Morris, Minnesota.

The lake and its watershed were sectioned into 10-acre cells for analysis (Figure 9). This analysis was based on the examination of variables including land slope, land shape, aspect of flow, soil characteristics, channel characteristics, cropping practices, fertilization rates, existence of feedlot areas, and point sources. The sediment and nutrient loading were modeled using a theoretical 10 year/24 hour storm event of 4.5 inches with an energy-intensity value of 129. Both nutrient loading values and watershed soil losses were evaluated.

The control of nutrient loading to a lake is very important. Phosphorus is responsible for limiting primary production in most freshwater systems and is consequently the principal focus in nutrient studies. Phosphorus is used in nearly all phases of metabolism, particularly in the energy transformation of phosphorylation reactions during photosynthesis. Phosphorus is required in the synthesis of nucleotides, phospholipids, sugar phosphates, and other phosphorylated intermediate compounds. Further, phosphate is bonded, usually as an ester, in a number of low-molecular-weight enzymes and vitamins essential to algal metabolism (Wetzel, 1983).

HUNTINGBURG LAKE
CELL NUMBERS

FIGURE 9



Nitrogen, however, can also play a major role in plankton metabolism and can expedite the eutrophication process within a lake. The phytoplankton productivity of infertile, oligotrophic lakes is often limited by the availability of phosphorus. As phosphorus loading to fresh waters increases and lakes become more productive, nitrogen often becomes the limiting nutrient for plant growth (Wetzel, 1983). Excessive loading of these nutrients permits increased plant growth until other nutrients and/or light availability become limiting (Wetzel, 1983). Inorganic nitrogen exists in three major forms, nitrate ions (NO_3^-), ammonium ions (NH_4^+), and molecular nitrogen (N_2). Several other intermediate forms of inorganic nitrogen exists, but are often quickly converted to one of the above stable nitrogen forms due to reduction-oxidation potentials. Oxidized inorganic and organic forms of nitrogen in the hypolimnion often contribute to hypolimnetic oxygen depletion as well.

Excessive algal growth is likely to occur when an abundance of nutrients are entering a lake. This increased algal growth can have several negative effects on a lake. Excessive algae will decrease the transparency of the epilimnetic (upper) waters. As the algae die, they drift from the trophogenic zone (a superficial stratum of a lake in which photosynthetic production predominates over respiration) to the hypolimnetic (lower) waters where they are microbially decomposed. These decomposition reactions are the primary consumptive process of oxygen from the hypolimnetic waters. The resultant impact on the biology of the lake is dramatic, particularly, the fishery of the lake.

Sediment is the most visible pollutant originating from nonpoint sources. After the soil has been transported to the lake by surface runoff, it is deposited in the inlets and along the shoreline. Effects of excessive sediment loading on receiving waters include deterioration in aesthetic values, loss of storage capacity in reservoirs, changes in aquatic populations and their food supplies, and accumulation of bottom deposits, which impose additional oxygen demand and inhibit some advantageous benthic processes (Novotny & Chesters, 1981). A negative economic impact is incurred by the farmer that losses the soil and nutrients.

3.61 Modeling Results

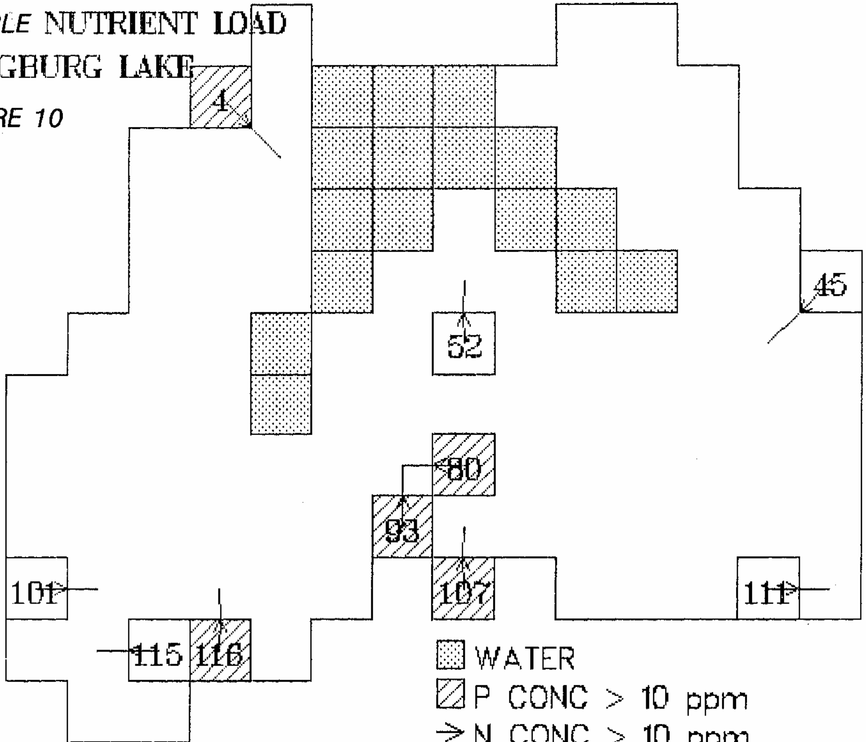
3.61A Nutrient Loading

There are two forms of nutrients that are modeled by AGNPS, soluble and sediment associated. The soluble nutrient values demonstrate the concentration of dissolved nutrients in the storm water when leaving a cell during a particular storm event. These values are reported in milligrams of nutrients dissolved per liter of water or parts per million (ppm). The sediment associated nutrient values represent that portion of a particular nutrient which leaves the cell attached to soil colloids suspended in the runoff during this particular storm event. These values are reported in pounds of a nutrient lost per acre of land.

The soluble nutrient data can been seen in Figure 10. This figure displays those cells that were in excess of 10 ppm of Phosphorus and/or Nitrogen. There are five cells that exceed

SOLUBLE NUTRIENT LOAD
HUNTINGBURG LAKE

FIGURE 10



this limit for Phosphorus, and ten cells that exceed this limit for Nitrogen.

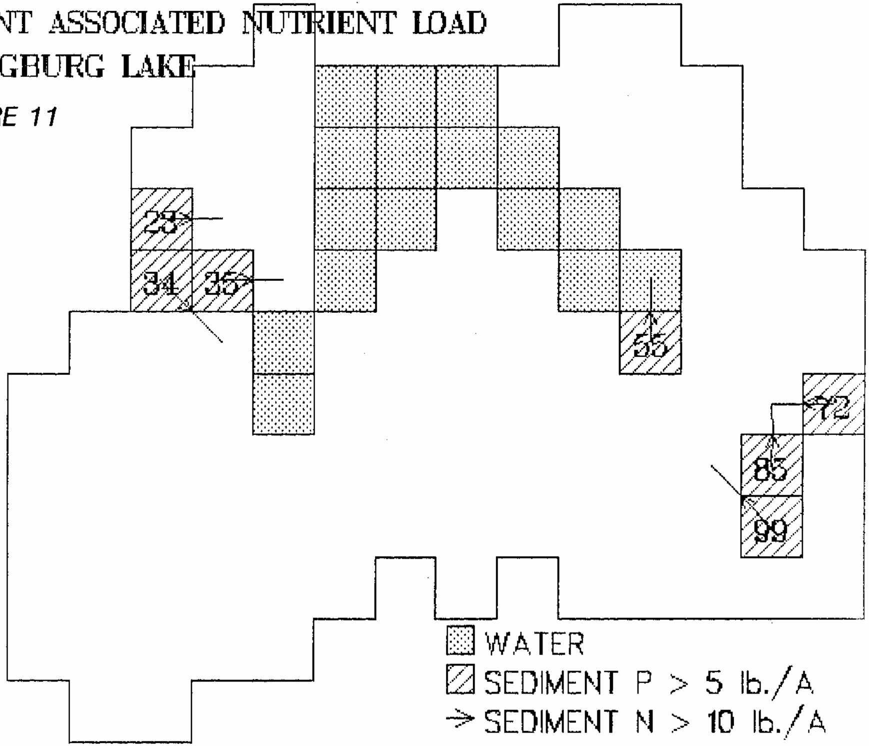
The sediment associated nutrient data can been seen in Figure 11. This figure displays those cells that lost in excess of 5 pounds per acre (lb./A) of Phosphorus as well as cells that lost in excess of 10 lb./A of Nitrogen during this storm event. For both nutrients, it was the same seven cells.

3.61B Soil Loss

The AGNPS model will calculate how many tons of soil are lost per acre of land for this storm event. Many references were located and contacted in an attempt to define an excessive erosion value for different types of soils. All the values however, were reported in units of mass/area/time such as tons/acre/year. No equations existed to corollate these estimates to single storm events. Mr. Bruce Lucord of the United States Department of Agriculture, North Central Soil Conservation Research Laboratory of Morris, Minnesota was involved in the writing of the AGNPS program. He stated that as a general rule, the USDA considers a loss of 5 tons/acre for a 25 year/24 hour storm event as excessive erosion. Donan Engineering then modeled Huntingburg Lake for a 25 year/24 hour storm event and located those cells that lost in excess of 5 tons/acre. A comparison was then modeled between the 25 year and 10 year events and found that setting a loss criteria of 3.7 tons/acre coincides with the same cells for the 10 year event as 5 tons/acre did for the 25 year event. Consequently, 3.7 tons/acre is the value chosen to represent excessive erosion. Figure 12 shows those 19 cells that lost at least 3.7

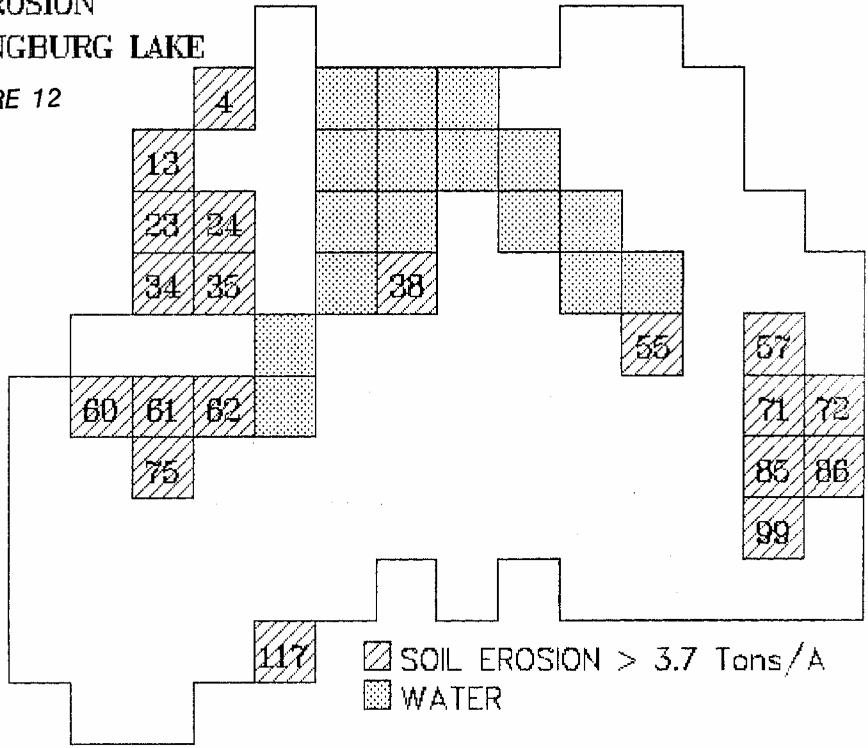
SEDIMENT ASSOCIATED NUTRIENT LOAD
HUNTINGBURG LAKE

FIGURE 11



SOIL EROSION
HUNTINGBURG LAKE

FIGURE 12



tons/acre for this modeled 10 year/24 hour event. The values of nutrients and sediments leaving at the watershed outlet are displayed in Table 18. The total sediment yield is estimated as 63.3 tons for this storm event.

3.62 Modeling Treatments

A fundamental advantage of AGNPS is its ability to model simulated land treatments. Two different land treatments were modeled for Huntingburg Lake. The first land treatment that was modeled was an ideal case of converting several high nutrient loading cells to ungrazed meadowlands. The second land treatment that was modeled concentrates on reducing the watershed soil loss and associated nutrients by implementing a 5 year reduced tillage/crop rotation plan.

Treatment One

As discussed in 3.61A, a total of only 17 cells out of the 119 watershed cells (16 of which were lake water) are contributing to high nutrient loads to Huntingburg Lake during a storm of this magnitude. Referencing the land use map, it can be seen that most of these cells consist of either cropland or pasture with some minor portions consisting of forest. Cells 45 and 111 were only high in soluble nitrogen. These two cells are almost exclusively forest; consequently, no land treatment will be simulated for these two cells. An ideal land conversion or treatment was modeled for the remaining 15 cells. The question was asked, "If it were feasible to convert these 15 cells from cropland and grazed pastures to ungrazed meadowlands, would the nutrient load be significantly reduced?". In order to model this ideal situation, seven

TABLE 18

Watershed Summary

Watershed Studied	HUNTINGBURG LAKE	
The area of the watershed is	1190	acres
The area of each cell is	10.00	acres
The characteristic storm precipitation is	4.60	inches
The storm energy-intensity value is	128	

Values at the Watershed Outlet

Cell number	8 000	
Runoff volume	2.3	inches
Peak runoff rate	814	cfs
Total Nitrogen in sediment	0.35	lbs/acre
Total soluble Nitrogen in runoff	1.86	lbs/acre
Soluble Nitrogen concentration in runoff	3.52	ppm
Total Phosphorus in sediment	0.17	lbs/acre
Total soluble Phosphorus in runoff	0.35	lbs/acre
Soluble Phosphorus concentration in runoff	0.67	ppm
Total soluble chemical oxygen demand	43.37	lbs/acre
Soluble chemical oxygen demand concentration in runoff	82	ppm

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Sediment Analysis

Particle type	Area Weighted Erosion Upland (t/a)	Area Weighted Erosion Channel (t/a)	Delivery Ratio (%)	Enrichment Ratio	Mean Concentration (ppm)	Area Weighted Yield (t/a)	Yield (tons)
CLAY	0.08	0.00	63	19	192.25	0.05	60.3
SILT	0.13	0.00	0	0	1.28	0.00	0.4
SAGG	0.80	0.00	0	0	1.50	0.00	0.5
LAGG	0.49	0.05	0	0	5.06	0.00	1.6
SAND	0.10	0.02	0	0	1.59	0.00	0.5
TOTAL	1.59	0.00	3	1	201.68	0.05	63.3

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parameter values were changed in the data file including, SCS Curve Number, Mannings Roughness Coefficient, Cropping Factor, Surface Condition Constant, Fertilizer Level, COD Factor, and Point Source Indicator. All other parameters including topography and soil types were left constant. The exact data changes are displayed in Table 19 with Table 20 displaying the results of this treatment. All soluble phosphorus values were significantly reduced from values ranging from 11 to 104 ppm to 3 ppm or less. The soluble nitrogen values were also significantly reduced from values ranging from 12 to 488 ppm to 1 to 46 ppm. All the sediment associated phosphorus values were reduced from values ranging from 5.10 to 11.26 lb./A to less than 1 lb./A. All sediment associated nitrogen values were reduced from values ranging from 10.21 to 22.53 lb./A to 1.6 lb./A or less. These results are also graphically displayed in Figures 13 & 14. The removal rates of nutrients and sediments leaving the watershed are displayed in Table 21. The total sediment yield is estimated at 42.1 tons for this storm event which is a reduction of about 33 percent.

Treatment Two

Every cell which indicated a loss of more than 3.7 tons/acre was cropland. These croplands were originally modeled using liberal cropping practices (i.e. continuous corn) which used a cropping factor of 0.18 for all farmlands. The second land treatment model concentrates on reducing the watershed soil loss and associated nutrients from these farmlands. This land treatment consisted of implementing a reduced tillage/crop rotation plan. This plan consists of a

TABLE 19

NUTRIENT TREATMENT - DATA CHANGES

ORIGINAL DATA

CELL #	RCN	MANN COEFF	C-FACT	SURF COND	FERT	COD	PT SOURCE
4	82	0.10	0.18	0.29	2	170	0
23	82	0.10	0.18	0.22	2	170	0
34	82	0.10	0.18	0.29	2	170	0
35	82	0.10	0.18	0.29	2	170	0
52	82	0.10	0.18	0.29	2	170	0
55	82	0.08	0.27	0.22	1	60	0
72	77	0.04	0.14	0.29	1	117	0
80	74	0.04	0.01	0.22	1	60	1
85	77	0.04	0.14	0.29	2	117	0
93	74	0.04	0.01	0.25	1	65	0
99	82	0.10	0.18	0.29	2	170	0
101	85	0.04	0.01	0.22	1	60	0
107	74	0.08	0.01	0.22	1	60	0
115	74	0.08	0.01	0.22	1	60	1
116	74	0.04	0.01	0.22	1	60	0

ALL ABOVE CELLS WERE CHANGED TO THE FOLLOWING VALUES:

	74	0.08	0.01	0.22	0	60	0

TABLE 20

CRITICAL NUTRIENT VALUES BEFORE AND AFTER CONVERSION TO PERMANENT UNGRAZED MEADOWLAND

SOLUBLE NUTRIENTS

PHOSPHORUS VALUES
(ppm)

CELL #	P - NOW	P - T
4	104	3
80	70	3
93	26	3
107	22	3
116	11	1

NITROGEN VALUES
(ppm)

CELL #	N - NOW	N - T
4	488	44
52	12	1
80	329	46
93	151	46
101	10	4
107	130	45
115	14	4
116	64	22

SEDIMENT ASSOCIATED NUTRIENTS

PHOSPHORUS VALUES
(lb./A)

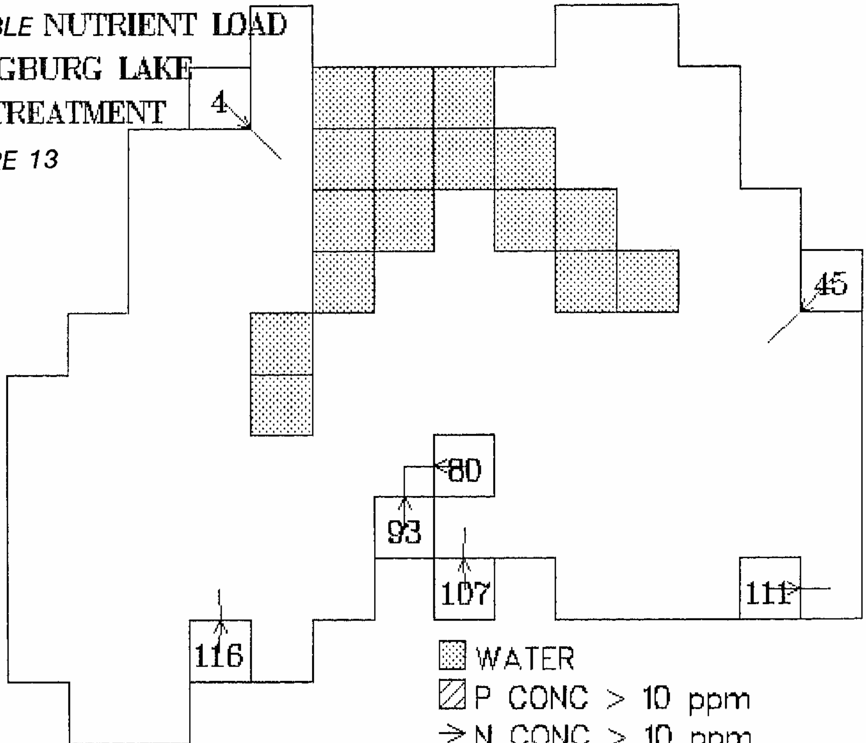
CELL #	P - NOW	P - T
23	7.74	0.77
34	5.10	0.52
35	5.10	0.51
55	11.26	0.80
72	6.63	0.78
85	5.11	0.60
99	5.75	0.58

NITROGEN VALUES
(lb./A)

CELL #	N - NOW	N - T
23	15.48	1.54
34	10.21	1.03
35	10.24	1.03
55	22.53	1.60
72	13.27	1.56
85	10.22	1.21
99	11.51	1.15

SOLUBLE NUTRIENT LOAD
HUNTINGBURG LAKE
AFTER TREATMENT

FIGURE 13



SEDIMENT ASSOCIATED NUTRIENT LOAD
HUNTINGBURG LAKE
AFTER TREATMENT

FIGURE 14

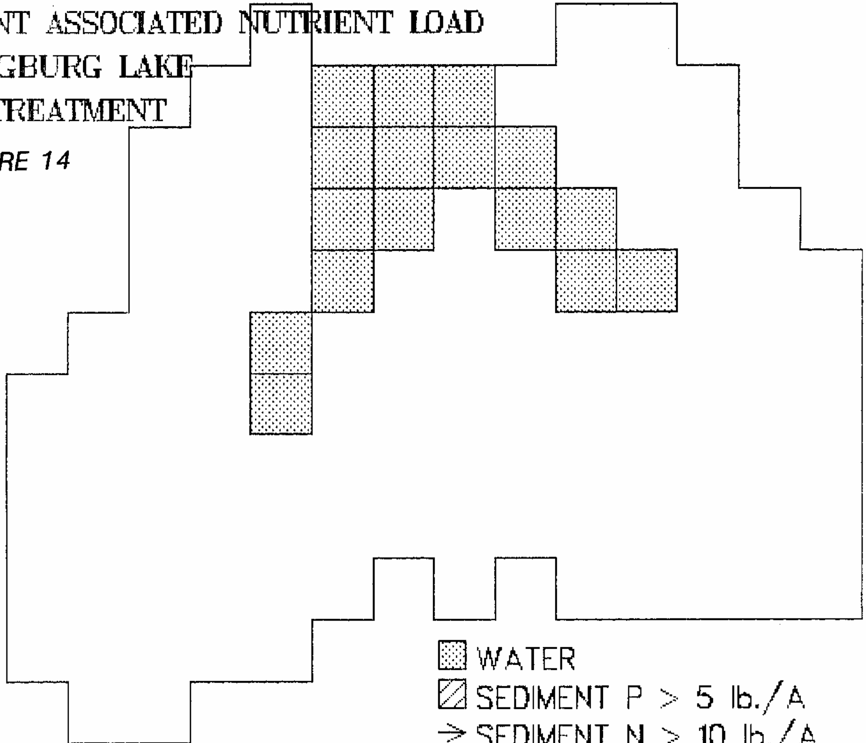


TABLE 21

Watershed Summary

Watershed Studied	HUNTINGBURG LAKE
The area of the watershed is	1190 acres
The area of each cell is	10.00 acres
The characteristic storm precipitation is	4.60 inches
The storm energy-intensity value is	128

Values at the Watershed Outlet

Cell number	8 000
Runoff volume	2.3 inches
Peak runoff rate	803 cfs
Total Nitrogen in sediment	0.25 lbs/acre
Total soluble Nitrogen in runoff	1.51 lbs/acre
Soluble Nitrogen concentration in runoff	2.91 ppm
Total Phosphorus in sediment	0.13 lbs/acre
Total soluble Phosphorus in runoff	0.27 lbs/acre
Soluble Phosphorus concentration in runoff	0.53 ppm
Total soluble chemical oxygen demand	38.61 lbs/acre
Soluble chemical oxygen demand concentration in runoff	74 ppm

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Sediment Analysis

Particle type	Area Weighted Erosion Upland (t/a)	Area Weighted Erosion Channel (t/a)	Delivery Ratio (%)	Enrichment Ratio	Mean Concentration (ppm)	Area Weighted Yield (t/a)	Yield (tons)
CLAY	0.05	0.00	63	19	126.62	0.03	39.1
SILT	0.08	0.00	0	0	1.28	0.00	0.4
SAGG	0.52	0.00	0	0	1.51	0.00	0.5
LAGG	0.32	0.05	0	0	5.10	0.00	1.6
SAND	0.06	0.02	1	0	1.60	0.00	0.5
TOTAL	1.03	0.00	3	1	136.11	0.04	42.1

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five year rotation starting with a no-til corn in crop residue. Following harvest, wheat would be planted in disced residue. In the second year, soybeans would be established using no-til in wheat stubble. In the fall, wheat would be sown as a cover crop in disced residue and grasses and legumes established. The third and fourth years would be exclusively hay. The fifth year management would include chisel plow, disk, and the planting of corn. The management practice would then repeat the rotation the next year with no-til corn in crop residue. This rotation plan produces an average cropping factor of 0.07 (See Table 22). As seen in Table 23 and Figure 15, the soil erosion was reduced by amounts ranging from 49.9 percent to 74.1 percent with cells averaging a 61 percent reduction; sediment associated nutrient loads were roughly reduced by 50 percent The loss of nutrients and sediments leaving the watershed are displayed in Table 24. The total sediment yield is estimated at 39.7 tons for this storm event which is a reduction of about 37 percent.

3.63 AGNPS SUMMARY

In conclusion, there are a few cells that would contribute excessive nutrient loads (dissolved and sediment associated) during this type of storm event. These nutrient loads and sediment loss rates can be successfully reduced by the conversion of all problem cells to permanent ungrazed meadowlands, implementing the proposed 5 year reduced tillage/crop rotation plan, or a combination of the two.

An important note is that the AGNPS model is a theoretical modeling of a particular storm event, and these recommendations

TABLE 22

Reduced Tillage and Crop Rotation
Five Year Plan

Year #	Management Practice	Treatment	Cropping Factor
1	1	-No-Til Corn in Crop Residue	0.09
1	2	-Wheat after corn in disked residue	0.05
2	1	-Soybeans no-til in wheat stubble	0.09
2	2	-Wheat after soybeans in disked residue grasses & legumes established	0.11
3	1	-Hay	0.01
4	1	-Hay	0.01
5	1	-Chisel plow, disk, plant corn	0.14
			0.50

Weighted Annual Average = 0.07

TABLE 23

CRITICAL SOIL EROSION AND ASSOCIATED NUTRIENT VALUES BEFORE AND AFTER IMPLEMENTING REDUCED TILLAGE AND CROP ROTATION PROGRAM

SOIL EROSION (Tons/A)

CELL #	BEFORE	AFTER
4	4.76	1.85
13	5.35	2.08
23	11.07	4.31
24	4.75	1.85
34	6.68	2.60
35	6.44	2.51
38	5.17	2.59
55	16.96	4.40
57	5.08	1.98
60	4.11	1.99
61	7.01	2.73
62	4.99	1.94
71	4.81	1.87
72	8.49	4.24
75	5.61	2.80
85	6.15	3.08
86	5.08	1.98
99	7.45	2.90
117	4.00	1.55

SEDIMENT ASSOCIATED NUTRIENTS

PHOSPHORUS VALUES (lb./A)

CELL #	BEFORE	AFTER
23	7.74	3.64
34	5.10	2.40
35	5.10	2.41
55	11.26	3.83
72	6.63	3.82
85	5.11	2.94
99	5.75	2.71

NITROGEN VALUES (lb./A)

CELL #	BEFORE	AFTER
23	15.48	7.28
34	10.21	4.81
35	10.24	4.82
55	22.53	7.66
72	13.27	7.64
85	10.22	5.89
99	11.51	5.41

SOIL EROSION
HUNTINGBURG LAKE
– REDUCED TILLAGE AND
CROP ROTATION

FIGURE 15

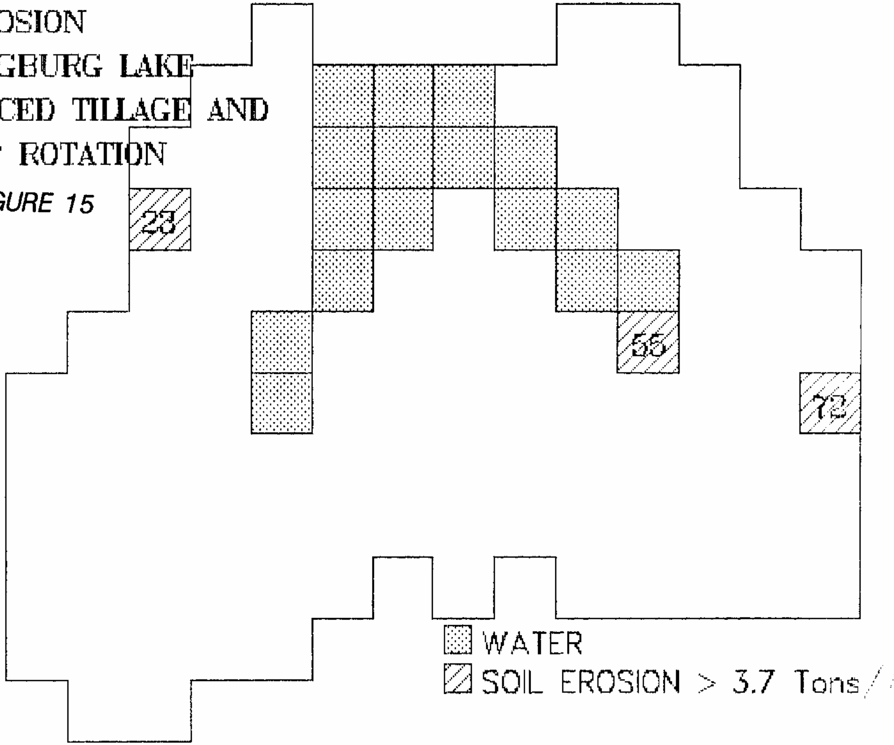

TABLE 24

Watershed Summary

Watershed Studied	HUNTINGBURG LAKE
The area of the watershed is	1190 acres
The area of each cell is	10.00 acres
The characteristic storm precipitation is	4.60 inches
The storm energy-intensity value is	128

Values at the Watershed Outlet

Cell number	8 000
Runoff volume	2.3 inches
Peak runoff rate	814 cfs
Total Nitrogen in sediment	0.24 lbs/acre
Total soluble Nitrogen in runoff	1.86 lbs/acre
Soluble Nitrogen concentration in runoff	3.52 ppm
Total Phosphorus in sediment	0.12 lbs/acre
Total soluble Phosphorus in runoff	0.35 lbs/acre
Soluble Phosphorus concentration in runoff	0.67 ppm
Total soluble chemical oxygen demand	43.37 lbs/acre
Soluble chemical oxygen demand concentration in runoff	82 ppm

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Sediment Analysis

Particle type	Area Weighted Erosion Upland (t/a)	Area Weighted Erosion Channel (t/a)	Delivery Ratio (%)	Enrichment Ratio	Mean Concentration (ppm)	Area Weighted Yield (t/a)	Yield (tons)
CLAY	0.05	0.00	63	19	116.99	0.03	36.7
SILT	0.08	0.00	0	0	1.28	0.00	0.4
SAGG	0.48	0.00	0	0	1.50	0.00	0.5
LAGG	0.30	0.05	0	0	5.06	0.00	1.6
SAND	0.06	0.02	1	0	1.59	0.00	0.5
TOTAL	0.96	0.00	3	1	126.42	0.03	39.7

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are ideal, hypothetical solutions. Septic systems often have significant nutrient contributions as well. However, AGNPS is not designed to implement septic tank data.

4.0 Introduction

G. Evelyn Hutchinson has established himself as an expert in the field of limnology. While serving as professor in the Department of Zoology at Yale University, he authored a multiple volume work entitled A Treatise on Limnology which is recognized internationally as the greatest limnological work of all times. Mr. Hutchinson quotes "Lakes seem, on the scale of years or of human life spans, permanent features of the landscape, but they are geologically transitory...to mature and die quietly and imperceptibly." (Hutchinson, 1957). The concept of which Mr. Hutchinson was referring to is known as eutrophication. Eutrophication is the aging process of a lake. All lakes and reservoirs undergo eutrophication. Eutrophication, by definition is "... the process of excessive addition of inorganic nutrients, organic matter, and/or silt to lakes and reservoirs, leading to increased biological production and a decrease in volume" (Cooke, 1986).

As a contrast, lakes and reservoirs exposed to the effects of human culture will in fact change very rapidly and conspicuously. This is known as cultural eutrophication. Lakes and reservoirs undergoing cultural eutrophication will lose much of their beauty, their attractiveness for recreation, and their usefulness as industrial and domestic water supplies. Rooted and floating plant masses may become so dense that many uses of the water are curtailed. Symptoms such as algal blooms, rapid loss of volume in reservoirs, noxious odors, tainted fish flesh and domestic water supplies, dissolved oxygen depletion, fish kills, and the development of nuisance animal populations (e.g. common carp) can bring about economic losses in the forms of decreased property values, high-cost treatment of drinking water, depressed recreation industries, expenditures for herbicide applications, and the need to build new reservoirs (Cooke, 1986). Huntingburg Lake is suffering from cultural eutrophication. It is already experiencing some of these symptoms and will no doubt experience all of these symptoms in time if no treatment is exercised.

The following treatments will focus on curtailing the cultural eutrophication that Huntingburg Lake is currently experiencing. Three different categories of treatments will be discussed. The first is current management techniques, the second is watershed management techniques, and the third is in-lake management techniques.

4.1 Current Management

The current management of the lake watershed includes the recent implementation of Indiana State Board of Health Rule 410 IAC 6-8, concerning residential sewage disposal system permits. This will to some degree restrict development of residential areas due to the predominance of soils that are unsuitable for conventional septic systems. Other management techniques, as set forth by City Ordinance No. 79-14, provide for restricted recreational use: swimming is prohibited; boats are limited to a size greater than 8 feet and less than 20 feet in length, with boat motors not to exceed 6 horsepower; camping is prohibited; and safety measures are required. The City Utility Board is granted the power and authority to prohibit, restrict or otherwise regulate all boats and other craft on the lake.

Another City ordinance is the zoning of a Conservation District around Huntingburg Lake providing for outdoor recreation, preservation of green areas, and conservation of the water resource. In this ordinance, residential dwellings are restricted to not less than 20-acre lots with sewage systems no closer than 500 feet from the ordinary high-water mark, or require approval by the Huntingburg City Plan Commission. This approval is subsequent to receipt of a written statement from the Dubois County Health Department approving the private sewage disposal system, assuring that no waste waters from the system will pollute the Huntingburg City Lake or the Patoka River.

Other than state and federal officials' jurisdiction concerning state and federal laws, it is assumed that the authority to enforce these ordinances in regards to trespass, discharge of detrimental liquids or solids, swimming and camping restrictions, and developmental regulations is that of the City.

Continuing the current management techniques would not be an adequate response to the critical problems facing Huntingburg Lake at this time, nor would it adequately insure future lake quality. External loading from the watershed and septic systems will continue to decrease the water quality by contributing nutrients, silt, organic matter, and bacteria. Under current condition, all facets of cultural eutrophication, as previously described, will eventually prevail.

4.2 Watershed Management Techniques

Watershed management is an extremely important lake restoration concept. A common principle known among lake managers and limnologists is that a lake is a reflection of its watershed. Watershed management techniques are the only ways to correct the causes of water quality problems and not just treat the symptoms. There are four existing conditions that can be addressed in Huntingburg Lake's watershed. The first is that there are livestock grazing throughout the watershed. The second is the cropping practices used throughout the watershed. The third is the septic systems used in the watershed. The fourth is the high representation (92%) of highly erodible soils in the watershed. These factors are promoting the eutrophication process at Huntingburg Lake.

The first watershed management practice addresses the existing conditions of livestock grazing, cropping practices, and highly erodible soils throughout the watershed. As seen by using the AGNPS computer model, nutrient loads can be successfully reduced by the conversion of all problem cells to permanent ungrazed meadowlands, implementing the proposed 5 year reduced tillage/crop rotation plan, or a combination of the two. The excessive soil loss can be reduced by implementing the proposed 5 year reduced tillage/crop rotation plan or meadows. Much of this agricultural acreage would also qualify for various SCS, or ASCS programs providing for permanent vegetation on a set-aside basis. In addition, livestock have access to the tributaries feeding into the lake. This contributes to stream bank erosion and potential contamination as well as nutrient loading from livestock waste directly entering the stream channel. This problem of stream channel contamination could be rectified by simply fencing off the grazing areas for livestock from the stream channel areas. The grazing of the woods along these stream banks is also a detrimental management practice and should be discouraged.

The second, third, and fourth watershed management practices address the existing condition of septic systems used throughout the watershed. As previously stated by the Indiana State Board of Health, Division of Sanitary Engineering (ISBH, 1987) and as recommended by the Indiana Department of Environmental Management (IDEM, 1986), a sewage collection system for the residential community on the watershed of Huntingburg Lake is also an important consideration.

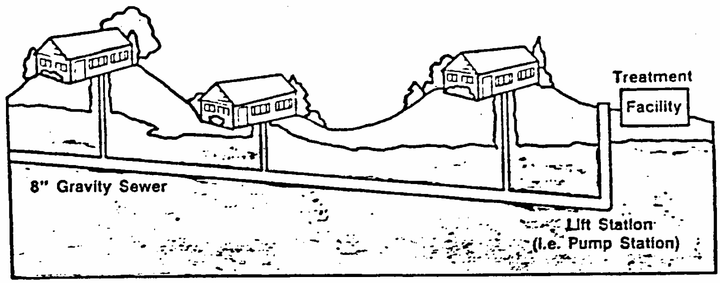
Septic tank maintenance programs would systematically insure that individual residences have properly functioning systems as a second watershed management practice. Those residents found to be out of compliance with state codes regarding sewage treatment would bear the cost of bringing their septic systems up to code. Due to the fundamental design of septic systems, the inherent characteristics of the watershed, and the close proximity of many of the residences to the lake and its tributaries, this program alone will not eliminate the pollutant load exerted by these septic systems, but will reduce their impacts.

Extending the city sewers throughout the watershed and requiring the hookup of residences to the line would be of considerable expense to the city averaging $8000 per household as a third watershed management practice. The length of sewer line required, the relief of the area, the necessity of a pumping station, and the spacing of residences in the watershed would further complicate implementing this alternative (Figure 16).

The implementation of a program utilizing small diameter effluent sewers is an alternative to conventional sewers as a fourth watershed management practice. These systems utilize one or more of three forces to convey wastewater to a centralized facility for treatment and disposal. These small diameter sewers make use of existing, functioning septic tanks. They require reduced diameter pipe (3 to 6 inches) due the suspended solids being removed by the individual septic tanks. The effluent from the septic tanks is carried by the pipe forced by gravity, pressure or vacuum to the centralized facility by way of hooking onto the existing city sewer lines (Figure 17). Cost for this type of system would range from $2000 to $4000 per household, one-fourth to one-half the cost of a conventional sewer system. Currently, there are approximately 35 residences on the watershed, 20 within close proximity to the lake and/or its tributaries. This system of wastewater treatment should be a primary consideration for those areas where it is not feasible to install conventional sewers. These systems may be financed in part by the

Conventional Gravity Sewers

EPA OFFICE OF WATER, 1987

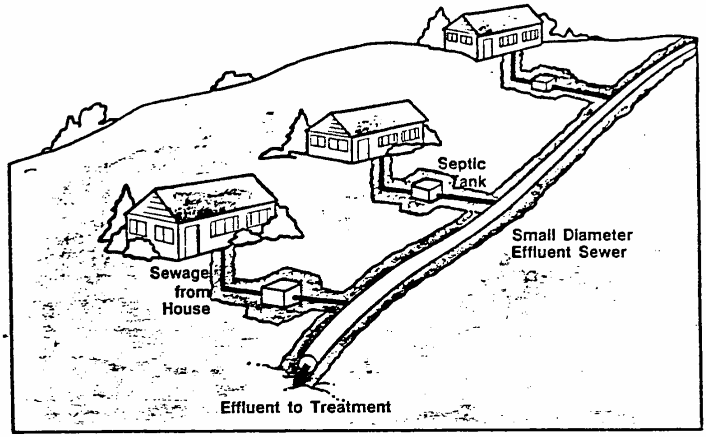


- Appropriate in densely developed areas (100 or more homes per mile of sewer: lot sizes 1/2 acre or less).
- Untreated wastewater travels mainly by gravity through a system of sewers and pumping stations.
- Difficult and expensive to install: must always slope downhill.
- Costly manholes are required for maintenance.
- Infiltration and inflow (leaky sewers) may be significant.
- Used alone or combined with other collection systems.

FIGURE 16 CONVENTIONAL GRAVITY SEWERS

Small Diameter Effluent Sewers

EPA OFFICE OF WATER, 1987



- ☐ Appropriate in less densely developed areas (less than 50 to 100 homes per mile of sewer: lot size 1/2 to two acres).
- ☐ Septic tank effluent (water flowing out of septic tanks) travels through a small diameter plastic pipe. Some homes may require a pump (STEP system) to move the effluent.
- ☐ Installed at shallow depths and may follow land contours: can be "woven" around trees and buildings.
- ☐ Septic tanks remove the solids: sewer clogging is generally not a problem even in low spots.
- ☐ Less costly cleanouts may be used in place of manholes.
- ☐ Smaller and simpler treatment facility can be used.
- ☐ Septic tanks should be pumped out every three to five years.
- ☐ Less possibility of infiltration and inflow.
- ☐ Use alone or combined with other collection systems.

FIGURE 17 SMALL DIAMETER EFFLUENT SEWERS

Environmental Protection Agency through the Indiana Department of Environmental Management or by the Farmers Home Administration in the form of grants and/or loans.

4.3 In-Lake Management Techniques

4.3.1 In-Lake Nutrient Control

Watershed management techniques are a first priority for limiting nutrient inputs. No in-lake restoration method is available that will yield long term solutions to improve water quality if watershed management techniques are ignored. However, even after external inputs of nutrients have been reduced it may be found that water quality is not improving quick enough. This often is the case since nutrients and contaminants increase in the sediments over time. These nutrients are cycled throughout the lake during different times of the year and will continue to promote excessive algal and macrophytic growth. When this occurs, internal recycling of nutrients needs to be controlled by implementing some form of in-lake treatment. This can be controlled through several in-lake methods such as (1) Phosphorus precipitation and inactivation through application of sodium aluminate (2) sediment oxidation (3) sediment removal or dredging or (4) hypolimnetic aeration or withdrawl. However, the recommendation of any of these in-lake treatment methods is premature. Watershed management techniques need to be implemented first; after which, a reassessment of the water quality should be made to determine if any in-lake treatment methods should be employed.

4.3.2 Influent Nutrient and Sediment Control

Wetlands and sedimentation basins are a separate type of restoration. After watershed management practices have been implemented, wetlands will often provide a very effective final filtration system before the water enters the lake. Properly maintained and/or properly designed wetlands can have many positive impacts on water quality. Wetlands are often referred to as "the kidneys of the landscape" for the functions they perform in hydrologic and chemical cycles. Wetlands have been found to cleanse polluted waters, prevent floods, protect shorelines, and recharge groundwater aquifers. Furthermore, wetlands play major roles in the landscape by providing unique habitats for a wide variety of flora and fauna (Mitsch & Gosselink, 1986). Wetlands are not considered a watershed management tool, but rather an in-lake treatment process. Therefore, wetlands alone would only address the symptoms and not correct the cause of the water quality problems. Although the marsh area of the west leg of the lake somewhat functions as a wetland, there are no other specific wetland areas around the lake. Wetlands could be developed on the east and west legs of the lake along the shore to provide natural nutrient and sediment filters. A wetland could aid in the uptake of iron and manganese from the acid mine seep in subwatershed 2. However, this would require the purchase of additional property by the City.

Sedimentation basins can often be constructed in conjunction with a wetland area. These basins provide a mechanism to collect the sediment before it enters the wetland. This will extend the life expectancy and the efficiency of the wetland. The construction of a sediment basin south of County Road 630 South in the marsh area of the lake would be a feasible in-lake restoration technique providing for nutrient-rich sediment removal, as well as further sediment retention and control. Approximately 13,020 cubic yards of nutrient-rich sediment should be removed. The cost of dredging would range from $2.00 to $5.00 per cubic yard yielding a range of $26,040 to $65,100 not including disposal costs. Disposal costs would be variable due to hauling distance, storage time, and potential value as fill and/or topsoil material. A permit from the U.S. Army Corps of Engineers may be necessary based on how the dredged material is stored, where it is placed, and other factors.

4.3.3 Aquatic Vegetation or Macrophyte Control

Chemical control of algae and macrophytes is not an alternative due to state and federal regulations concerning primary potable water supplies. Harvesting of macrophytes along the lakeshore would reduce aquatic cover for the reduction of the stunted panfish and gizzard shad populations, but would require removal of the cut vegetation so as not to provide an immediate source of nutrients to the lake. There are specially designed harvesting tools and equipment that would adequately work, ranging in cost from $80 to $400.

SECTION 5. PREFERRED ALTERNATIVE

A preferred alternative for Huntingburg Lake responds to numerous factors influencing the lake water quality while addressing cost-effectiveness, and recreational lake usage of the primary water facility of the City of Huntingburg.

The City of Huntingburg has to deal with some difficult issues regarding conflicting land uses. It cannot be argued that conflicting interests exist between farmers and residents of the watershed and the entire City of Huntingburg that uses the reservoir as their primary drinking water supply. Huntingburg lake has been abused over the past several years in regards to nutrient and sediment inputs. Due to this history of abuse, the lake is more susceptible and fragile with respect to nutrient and sediment loads. The AGNPS model demonstrated that if certain cells were converted to permanent ungrazed meadowlands, the nutrient inputs of the watershed can be reduced significantly during storm events. The reality of this actually occurring without any participation by the City of Huntingburg is highly unlikely. The AGNPS model also demonstrated that if farmers would implement the proposed 5 year reduced tillage/crop rotation plan, sediment and nutrient loading would be held to a tolerable limit. The City of Huntingburg may also want to participate in promoting this plan. Promoting and enforcing these two concepts should be the primary treatment alternative for Huntingburg Lake.

The City of Huntingburg should work closely with the Dubois County Soil and Water Conservation District (SWCD) to implement watershed erosion control measures and develop a lake and watershed management plan. The Lake Enhancement Program is currently working to develop a Lake Watershed Land Treatment Program. The program is designed to provide cost-sharing and incentive payments to landusers in the watershed of a Lake Enhancement project lake for implementing land treatment practices that reduce sediment and nutrient inflows to the lake from agricultural sources. The Lake Watershed Land Treatment may be a potential source of funding for watershed treatment at Huntingburg Lake. However, the program will not begin wide-scale funding of projects until 1992.

There are several other watershed management techniques that should be implemented in conjunction with the above two concepts. The design and implementation of erosion control structures should also be considered. These would be a part of the T by 2000 Cropland Erosion Control Program on a cost-share basis with the landowner. Streamside management zones should also be implemented as recommended by the SCS providing buffer zones along the lake and its tributaries. These streamside management zones would provide for the protection of lake tributaries from animal waste contamination and stream bank erosion, in addition to serving as vegetative filters for sediment and nutrient entrapment. Water and soil erosion control basins (WASCOBS) and other drop structures should be implemented on eroded areas on the lake watershed specifically in heavily grazed areas or at eroded edges and drainage ways in crop fields. Design and construction of these structures would be implemented with assistance by the USDA Soil Conservation

Service in conjunction with the IDNR Division of Soil Conservation as part of the T by 2000 Cropland Erosion Control Cost Share Program.

Zoning and development regulation to protect the watershed for the long-term water quality of Huntingburg Lake as the city's primary water source is a fundamental consideration. This management technique provides the standards and foundation for the implementation of several of the recommended alternative management techniques.

A second primary response is the development of a small diameter effluent sewer system to eliminate the residential sewage contamination of the lake. Approximately 22 residences lie within 12,000 feet of the city sewer lines along Old Highway 64 and County Road 630 South. Seven residences are on the southwest extent of the watershed along Old Highway 64. Four residences are in close proximity to the northeast part of the lake, with the remaining residences along the eastern edge of the watershed (Watershed Land Use Map, Appendix). Along County Road 630 South and east of the junction with Old Highway 64, small diameter effluent sewers should be established hooking up approximately 22 residential septic tanks to the city sewer lines. The additional residences on the outlying areas of the watershed should undergo systematic septic system maintenance to insure maximum efficiency of the septic systems. This may require construction of acceptable septic systems based on location and specific land characteristics. An additional consideration would be to run another 6000 feet of small diameter line out 3rd Street and along State Highway 64 picking up 16 residences as well as the country club. Six of these residences are in the watershed. A Construction Permit will be required by the Office of Water Management at the Indiana Department of Environmental Management. The City of Huntingburg may apply for funding from the State of Indiana.

A third primary response is to dredge the marsh area on the west leg of the lake to further aid in sediment control and remove nutrient-rich sediments that have accumulated. A design study should be conducted to provide for the construction and maintenance of this area as a silt basin to aid in reducing sediment loading into the lake, as well as provide for proper drainage of these subwatersheds. A permit may be required from the U.S. Army Corps of Engineers for the dredging operation, and a Construction in a Floodway Permit will be required by the Indiana Department of Environmental Management.

A fourth primary response is the mitigation of the acid mine seep by developing a wetland or diverting the seepage out of the watershed. A design study should determine which alternative is practicable based on comparative construction costs as well as geologic conditions. The significance of this point source contamination may increase as the buffering material(s) present in the shafts or originating in the soils are decreased or exhausted, especially with the parent material of the soils in this area being sandstone, shale and slate.

These four responses combine as the preferred alternative addressing nutrient loading, sedimentation, septic contamination and acid mine drainage at Huntingburg Lake as shown in Table 25. This or any other set of management technique alternatives selected to be implemented at Huntingburg Lake should be a part of an overall lake management plan and have a foundation in city regulation and/or ordinance to provide for the long term care and protection of Huntingburg Lake. The plan should provide for the management of the lake and its tributaries, the regulation of recreational lake usage, and the systematic monitoring of lake water quality and eutrophication indicators, such as: transparency, turbidity, odor, bacterial counts, aquatic vegetation, and fish populations. The City of Huntingburg must decide how important this lake is as a future potable water supply. If the decision is made that it is worth protecting, restoration alternatives should immediately be implemented and enforced.

Table 25. Preferred Lake Management Techniques

Priority	Description	Cost	Funding
1. Watershed Management	a. Conversion of certain fields to permanent ungrazed meadowlands	a. ---	a. CRP Program Feed Grain Programs
	b. Implement 5 year reduced tillage/crop rotation plan	b. ---	b. Ag. Conserv. Program
	c. Streamside Management	c. Implemented by SCS and landowners	c. May be funded in part by IDNR, Div. Soil Cons., and SCS
	d. Zoning and development regulation	d. ---	d. ---
2. Wastewater Treatment	a. Small Diameter Effluent Sewer System for 22 residences	a. $44,000 to $88,000; septic tank repair incurred by resident	a. May be funded in part by, FmHA, EPA and/or State of Indiana
	b. Septic Tank Maintenance Program for 13 residences	b. Septic tank repair incurred by resident	b. ---
3. In-Lake Restoration	a. Dredging and construction of silt basin	a. $26,040 to $65,100	a. May be funded in part by IDNR, Div. Soil Cons.
4. Point Source Treatment	a. Mitigation of Acid Mine Seep	a. Unknown	a. May be funded in part by IDNR Div. of Reclamation, and/or EPA

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